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(54) Title: APPARATUS FOR SUPPLYING RADIOACTIVE GAS TO A DELIVERY DEVICE <div data-bbox="483 1142 1138 1528" data-label="Image"> </div> (57) Abstract Disclosed is a catheter apparatus filled with a radiation carrier material such as an inert radioactive gas for the treatment of restenosis after angioplasty, and malignancies. The inflated catheter includes a single unit or alternatively, a plurality of discrete chambers for transporting the radioactive carrier material and through which, blood may continue to flow during treatment with the prescribed radiation. When the radioactive carrier is a gas such as Xenon 133, an injection apparatus (1400) may be used that permits use of a standard radioactive gas source vial (1401) that may be loaded into the radioactive source vial enclosure or chamber (1403). The means for enclosing the vial (1404) may also serve as an urging mechanism (1442) to urge the source vial (1401) toward one or more piercing cannulae (1406, 1454) which permit delivery of the radioactive gas to the catheter. In one series of embodiments, the radioactive gas is withdrawn through a selector means (1409) such as a multiple position valve into a gas-tight variable volume chamber (1411) such as a syringe which then is deployed to deliver the gas into the catheter. Following treatment, the gas is withdrawn into the syringe and returned to the source vial (1401). In another series of embodiments a syringe filled with a liquid is used to displace the gas either directly into the delivery catheter (1422), or into a second syringe which injects the gas to the delivery catheter (1422).		

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APPARATUS FOR SUPPLYING RADIOACTIVE GAS TO A DELIVERY DEVICE

DescriptionTechnical Field

This invention relates generally to medical devices and, in particular, to an apparatus used in the delivery of medical radiation treatment to a patient.

Background of the Invention

5 Angioplasty is an established procedure for reducing the effect of atherosclerotic plaque on and intraluminal narrowing of the arterial walls within the vascular system of the patient. The effect is reduced by use of a catheter that is inserted into the site of the diseased-occluded vessel. A balloon portion of the catheter is then inflated to a predetermined pressure range and size, to radially
10 compress the plaque occlusion, thereby increasing the internal diameter of the previously restricted artery. The balloon is then collapsed and the catheter is removed.

 After the angioplasty procedure has been performed, as many as one-third to one-half of the patients soon develop restenosis. Restenosis can occur after
15 angioplasty or other recannulation procedures, with or without stenting, wherein the migration and proliferation of benign cells cause a restenotic lesion to form, resulting in the further blockage of the intravascular structure.

 Radiation is administered to patients for a variety of reasons, such as to treat restenosis, malignant or benign tumors, or the like. Examples of such
20 treatments are disclosed in U.S. Patent Nos. 5,059,166; 5,213,561; and 5,302,168.

 It would be preferred to be able to provide a radiation delivery system which would:

 a) deliver a predetermined totally-cumulative and homogenous dose of radiation to the lesion site, at a predetermined penetration depth, while minimizing
25 the exposure of surrounding healthy tissue to the radiation;

 b) enable the treating physician or other health-care personnel to be bedside to the patient during the administration of the radiation therapy without exposing the physician or health care personnel to any unreasonable risk;

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c) use radiation material that is readily and inexpensively available from a commercial provider;

d) use minimal special equipment storage, or delivery devices, except for routine facilities available in most nuclear medicine or radiation oncology departments;

e) use a radiation carrier material that if applied as an unsealed free-gas form, the inert, noble gas properties essentially enable the molecules of the carrier material to rapidly dissipate throughout the body of the patient without any prolonged organ accumulation or chemical interaction, and rapid dilution of the carrier material is quickly re-released from the bloodstream through the lungs;

f) minimize long term occlusion of normal blood flow during therapy, thereby providing more flexibility as to administration time and dosage;

g) use a radiation carrier material that is a stable and which can be pressurized, stored, and made to high millicurie activity per cubic centimeter with reasonable cost and availability;

h) use beta particles having excellent initial dose rate delivery and energy transfer when directly adjacent to the targeted tissue within the first one millimeter, and not penetrate much beyond this depth;

i) use gamma photon energies having depth doses that provide complementary dose deposition with the beta particles for the first one millimeter, and primary additive dose delivery for an additional two to three millimeters of the targeted tissue;

j) use these beneficial physical and biological radiation properties for treating restenosis, and malignancies (for example - in the brain, lung, esophagus, trachea, cervix, biliary ductal system, colon or rectum, the gastrointestinal system, the gynecological system, or head and neck) and other internal ailments where an internal application of radiation directly applied to the tissue may be needed; and

k) attenuate the transmission dose to blood circulating through the apparatus, and while creating increased by-product radiation, delivering useful radiation dose over hundreds of micrometers of target tissue.

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In order to accomplish these primary objectives, it would be desirable to have the device for delivering a therapeutic dosage of radioactive fluid to include a means to supply the treatment device with a given dosage of radioactive fluid from a source reservoir and then transfer the fluid back to the source reservoir at the completion of the treatment. Current systems for delivering radioactive gas, primarily designed for lung inhalation studies, lack the ability to retrieve the gas once it is introduced into the patient. Various syringe-type devices are known in the art for the purposes of delivering gas or inflating balloon catheters, however, they lack the safeguards necessary for working with radioactive gas, such as proper shielding and leakage prevention features that protect the patient and clinical personnel. In addition, it would be desirable to have a system whereby the standard commercially-available radioactive source vial with a pre-calibrated radioactive dosage could be directly loaded into the injection apparatus rather than relying on a standard syringe system which requires that a technician transfer or preload the radioactive material into the apparatus prior to the procedure, requiring additional handling and calibration.

Summary of the Invention

The foregoing problems are solved and a technical advance is achieved in illustrative medical radiation treatment delivery apparatus such as an inflatable balloon catheter for delivering radiation to a treatment site. In particular, the apparatus has a portion such as the inflatable balloon through which radiation from a radioactive fluid such as an isotope of xenon can be radiated therethrough. The balloon normally has a radiation dosimetry unit of measurement such as a radiation dose rate which heretofore had to be calibrated by a physicist or medical radiation expert for providing a prescribed radiation dose within prescribed limits to the patient. This radiation dosimetry unit of measurement is advantageously indicated by the manufacturer and affixed, disposed or positioned on the delivery device as an indicator of the radiation dosimetry unit of measurement.

In one embodiment, the dosimetry unit is simply displayed on or near an end of the catheter apparatus with one or more symbols, letters, or numbers indicative of the dosimetry unit. The indicator can be affixed, disposed, or positioned

thereon by printing, photoetching, painting, embossing, raising, or any other method of marking.

In another aspect, the indicator can be a radiation sensitive film which is sensitive to radiation for changing from one visible shade to another. This advantageously can be used to supply information to the attending physician for the purposes of radiation treatment and, in particular, achieved total delivered dose *in vivo*. Furthermore, this radiation sensitive film can be used either alone or in combination with one or more other dosimetry use indicators to provide the attending physician with a host of information concerning the properties of the catheter or delivery apparatus or the use thereof in patients.

The elongated member of the catheter apparatus comprises at least one of a polyurethane, polyethylene, polyimide, polyvinyl chloride, polyamide, polytetrafluoroethylene, silicone material, or any other similar suitable material. A high density material of at least one of barium, tungsten, lead, tantalum, titanium, bismuth, gold, platinum, palladium, rhodium, or any other similar suitable material is also included in the elongated member to advantageously control the dosimetry unit of the catheter as well as provide radiation shielding for the patient and attending personnel. Similarly, the material of the portion of the delivery apparatus that comes in contact with the treated tissue such as the inflatable balloon(s) advantageously includes at least one of silicone, latex, a synthetic material similar to latex, polyamide, vinyl, polyethylene, polytetrafluoroethylene, polyethylene terephthalate, fluorinated ethylene propylene, or any other similar suitable material. Selection of the balloon material and its density and thickness affect the radiation dosimetry unit of measurement such as the radiation dosage rate. High density materials as previously mentioned, also are advantageously utilized to control the dosimetry unit.

The system of the present invention is useful for the administration of ionizing or other types of therapeutic radiation. The intravascular catheter system of the present invention uses either of several unique radiation carrier fluids. The catheter apparatus includes either a plurality of balloon sections or a single balloon unit which is inflatable by an inert radioactive carrier fluid (liquid or gas). In one

aspect, blood or other body fluid flows through the artery or tube and possibly the catheter when the balloon sections are deflated and inflated. When the balloon(s) of the several embodiments is inflated, the blood flows through at least one section(s) disposed between and/or within the balloon section(s). The system can
5 also be readily modified for tissue or organ-specific design to treat malignancies in passageways or tubes of cancer patients, or even injecting the radio-contents of the catheter into tissue in a limited, controlled manner.

In one embodiment of the present invention, one catheter can perform the two functions of angioplasty as well as the treatment of restenosis, although specific
10 expansion pressures would need to accurately accommodate allowances for tissue dosimetry with respect to balloon thickness, density, materials, etc. The radioactive fluid can initially be used to expand the balloon section, to perform the angioplasty, and then left *in situ* to prevent or minimize restenosis. Alternatively, the initial expansion for the angioplasty can be performed by introduction of a discrete fluid
15 such as a liquid, which can be removed and replaced by the radioactive fluid such as a radioactive gas. Multiple separate lesions can be treated with the same catheter. As another alternative, the same balloon with radiofluid/xenon gas can be used for synchronous brachytherapy with stent placement.

As a further alternative, the angioplasty catheter can, after it has fulfilled
20 its normal function, be withdrawn and replaced by the catheter apparatus described herein. A lesser number of changes of the catheter is better for the patient, since any intrusion into the body, especially the coronary arteries, can be damaging.

The catheter is designed to be capable of direct insertion into any tumor as well as pseudocavities or defects after surgical or other debulking/resection
25 procedures, or to be maneuverable into a position adjacent to a tumor such as by being maneuverable into a body cavity or along a body passageway through which body fluids will pass. When the catheter is used in a vein or artery, the device can be made to permit the flow of blood within the catheter such as between and/or inside the balloon or balloons or to maintain perfusion flow via the central lumen.
30 Provision is also made for variable balloon(s) thicknesses to provide radiation shielding for the blood and/or redirecting the radiation to the treatment tissue.

Shielding can also be utilized by an outer shield surrounding the balloon(s). The outer shield can be pulled back proximally to allow the balloon(s) to inflate fully or partially. The proximal end of the outer shield in combination with markings on the proximal end of the catheter are utilized as a dosimetry unit indicator. This is accomplished by varying the volume of the inflatable balloon(s). As the outer shield is pulled back, the length of the balloon(s) that is allowed to inflate increases, thereby increasing the volume of the balloon(s). This, in turn, affects the total radiation dose, radiation dosage rate of the balloon(s), etc. The change in length is calibrated and indicated by the combination of the markings on the proximal end of the catheter and the proximal end out of the outer shield. In addition to being a dosimetry unit(s) indicator, the outer shield also advantageously provides radiation protection to non-treatment site tissue of the patient and to attending personnel.

The balloon section can either comprise a single balloon or a plurality of balloons arranged on the catheter section either peripherally or longitudinally or both. The section is inflated by the radiation fluid that causes the exterior parts of the balloon(s) to improve contact with the tissue to be treated. There can be an exterior inflatable coating of the catheter movable into contact with the tissue. The contact can also be direct between the balloon(s) and the tissue to be treated. The wall of the balloon(s) in the region of the tissue to be treated is of reduced thickness in order to maximize the radiation to the tissue. The thickness obviously must be sufficient to prevent leakage of radiation fluid. The higher the activity, the more important the question of leakage becomes. The balloon when inflated with a radioactive gas such as xenon can also conform to the tissue to be treated to provide homogenous radiation delivery.

The treatment method of the present invention can be applied to a patient either after angioplasty has been performed, or for treating malignant tissue within the brain, lung, esophagus, trachea, cervix, biliary ductal system, colon or rectum, the gastrointestinal system, the gynecological system, on the skin, on ocular structures, head and neck, or other areas accessible to this catheter technology.

The method is designed to apply ionizing radiation prophylactically to post-angioplasty vascular tissue or tumors internal to a patient while minimizing

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exposure of healthy tissue. Initially, the location and the size of the tissue to be treated are clinically identified, perhaps, with a fluoroscope. The catheter apparatus is then introduced and positioned adjacent to or within the tissue to be treated. The catheter apparatus is then inflated by the radioactive fluid (e.g., gas) thereby exposing the tissue to be treated to radiation. The catheter can include a plurality of discrete balloon sections with special and hypo-dense material, which enable the inflated catheter to match and/or conform more closely with the internal tissue wall, and minimize the amount of gas loss internal to the patient in the event of leakage. In one embodiment of the invention, the inflation lumen of the delivery catheter is minimized to decrease the amount of radioactive fluid in the delivery catheter, as well as the amount required in the injection source. The catheter apparatus can include an outer retractable radiation sleeve or shield to prevent the exposure of healthy tissue to radiation. In addition, the radiation shield can be used to control the delivery of radiation to the tissue to be treated. The radiation shield is then retracted to a specific measurable length. Preferably, the radioactive fluid is an inert gas, such as xenon or an isotope of xenon, and emits beta and gamma particles into the tissue to be treated. The catheter apparatus can also include a outer layer containing a shielding material that is deposited upon the outer surface of the catheter by one of several well-known methods. Alternatively, the shielding layer can be comprised of a film that is bonded to or shrunk over the outer surface of the delivery catheter.

A specific coating of integrated and/or layered transitional metal or metal alloy compounds from the surface to the center of the gas exposed side of the wall of the central catheter lumen enhances the radiation dose delivered to the targeted tissue. The wall of the lumen attenuates transmission dose to the blood circulating through the hollow inner lumen of the catheter device. Also, the system creates increased by-product radiation, from the impact of beta particles and gamma photons traveling toward the lumen wall. This energy would otherwise be wasted as treatment dose, but instead produces by-product low-energy x-ray photons which increase the deposited energy dose into the target tissue via scattered angle coincidence or secondary redirected x-ray production from the slowing of beta particles traveling into the metal compound on the wall surface. The by-product

x-rays travel through the balloon outer wall and deliver useful radiation dose to the targeted tissue (Bremmstrahlung).

Another embodiment includes first and second opposing and separate, semi-circular balloons with opposed support displacers attached just proximal and distal to the balloon lengths, upon the outer lumen wall. The built-in injection port unit enables gas-tight redirection of radioactive gas flow from one balloon to the other, one balloon being inflated and delivering treatment dose, while the opposing balloon is deflated. The support displacers are juxtaposed against the vessel wall enabling blood to flow more easily through the space opposite to the treatment side.

In another aspect of the invention, the medical radiation treatment delivery apparatus includes an radioactive gas injection apparatus that is comprised of enclosure for receiving a radioactive gas source vial; at least one cannula to pierce the vial septum; a variable-volume chamber, such as a gas-tight syringe, for supplying the positive pressure to inflate the balloon catheter; and an interconnection means to transfer the gas from the vial to either the syringe or directly to the delivery device and if necessary. The apparatus also has the ability to retrieve the gas from the delivery device and transfer the remaining gas back into the source vial following treatment.

In one embodiment of the injector means, the apparatus includes a multiple position valve that allows the operator to interconnect the source vial and syringe for filling the syringe with gas, switch the valve so that the syringe communicates with the delivery catheter, and then switching back to the previous position after the gas has been withdrawn back into the syringe to return the gas to the original source vial. A third position of the valve allows gas remaining in the passageways and valve to be removed via an external vacuum line. A fourth valve position prevents communication between the forementioned elements.

In another embodiment of the injector means, a separate fluid-filled syringe is used to displace the radioactive gas into the syringe. The valve position is then switched to allow the syringe to communicate with the delivery catheter. The fluid in the source vial is withdrawn into the separate syringe, and once the gas is withdrawn back into the main syringe, it is expelled back into the source vial.

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In still another embodiment of the injector means, the separate fluid-filled syringe pressurized a vial chamber to force the vial downward where it is punctured by the piercing cannula.

5 In yet another embodiment of the injector means, the syringe, is filled with fluid which is used to displaced the gas from the source vial. The displaced gas exits the vial through a second cannula and is directed into the delivery catheter. This embodiment optionally includes a vacuum-operated safety latch that prevents puncture of the source vial unless the scavenger vacuum system is in operation.

10 In still yet another embodiment of the injector means, the enclosure chamber housing the source vial and multiple position valve acts as a plunger to compress the volume of a chamber formed within the main housing of the apparatus that holds gas transferred from the source vial.

Brief Description of the Drawings

15 As the invention can be embodied in many forms without departing from the spirit of essential characteristics thereof, it is expressly understood that the drawings are for purposes of illustration and description only, and are not intended as a definition of the limits of the invention. Throughout the description, like reference numbers refer to the same component throughout the several views.

20 FIG. 1 is an assembly drawing of one embodiment of the catheter system of the present invention;

FIG. 2 is a detail sectional view of the deflated catheter apparatus taken along line 2-2 of FIG. 1;

FIG. 3 is a detail sectional view of the fully-inflated catheter apparatus taken along line 3-3 of FIG. 2;

25 FIG. 4 is a detail sectional view of the deflated catheter apparatus taken along line 4-4 of FIG. 1;

FIG. 5 is an enlarged sectional view of the engagement between the protected, syringed gas supply and the catheter apparatus of FIG. 1;

30 FIG. 6 is a detail sectional view of the fully-inflated catheter apparatus as shown in FIG. 1 inside an arterial wall;

FIG. 7 is a second embodiment disclosing a detail sectional view of a balloon of a catheter apparatus being fully-inflated and having a thickened interior wall and a thinner, hypo-dense outer wall;

FIG. 8 discloses a detail of an inflated balloon of the catheter apparatus shown in FIG. 7;

FIG. 9 discloses a third embodiment of the catheter apparatus having a removable central lumen guide/localizing wire that is radio-opaque;

FIG. 10 is a detail sectional view of the fully-inflated catheter apparatus of FIG. 9 within the arterial wall;

FIG. 11 is an assembly drawing of a fourth embodiment of the catheter system of the present invention with the catheter apparatus being deflated;

FIG. 12 discloses a detail view of the fully-inflated catheter apparatus of FIG. 11;

FIG. 13 is a detail sectional view of the fully-inflated catheter apparatus taken along line 12-12 of FIG. 12;

FIG. 14 is a detailed sectional view of the fully-inflated catheter apparatus of FIG. 11;

FIG. 15 is an exploded sectional view of a fully-inflated balloon of the catheter apparatus of FIG. 14, the balloon having a thickened inner wall and a thinner hypo-dense outer wall;

FIG. 16 is a detailed sectional view of the partially-inflated catheter apparatus of FIG. 11, complete with the retractable sleeve;

FIG. 17 is a fifth embodiment of the present invention disclosing a deflated catheter apparatus for use in treating malignancies in an organ such as the brain, esophagus, lung, or colon;

FIG. 18 is a detail view of the inflated catheter apparatus of FIG. 17;

FIG. 19 is a detail sectional view of the pressure-sensitive flapper valve for the inflated catheter apparatus taken along line 19-19 of FIG. 18;

FIG. 20 is an enlarged assembly drawing of a sixth embodiment of the catheter system of the present invention, with a single balloon fully inflated as the blood flows through the center section of the apparatus;

FIG. 21 is an end view of the catheter system of FIG. 20;

FIG. 22 is an enlarged assembly drawing of a seventh embodiment of the catheter system of the present invention, with two separate, semi-circular balloons, one balloon being inflated and delivering a treatment dose, while the opposing balloon is deflated;

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FIG. 23 is a end view of the catheter system of FIG. 22;

FIG. 24 is a side view of the catheter system of FIG. 22.

FIG. 25 is an enlarged, pictorial, proximal end view of the catheter apparatus of FIG. 1 with a radiation dosimetry unit(s) indicated thereon;

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FIG. 26 is an enlarged, pictorial, proximal end view of the catheter apparatus of FIG. 1 with a radiation dose rate indicated thereon;

FIG. 27 is an enlarged, pictorial, proximal end view of the catheter apparatus of FIG. 1 with a total radiation dose indicated thereon;

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FIG. 28 is an enlarged, pictorial, proximal end view of the catheter apparatus of FIG. 1 with an alternative embodiment of an indicator thereon;

FIG. 29 is an enlarged, longitudinally sectioned view of the elongated member of the catheter apparatus of FIG. 1 taken along a line through the dosimetry indicator thereof;

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FIG. 30 is an enlarged sectional view of an alternative embodiment of the radiation sensitive film of FIG. 28;

FIG. 31 is an enlarged sectional view of another alternative embodiment of the radiation sensitive film of FIG. 28;

FIG. 32 is an enlarged, partially sectioned view of the catheter apparatus of FIG. 1 with a dosimetry unit indicator thereon;

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FIG. 33 is an enlarged, longitudinally sectioned, proximal end view of the catheter apparatus of FIG. 1 with still another alternative embodiment of an indicator thereon;

FIG. 34 is an enlarged, longitudinally sectioned, proximal end view of the catheter apparatus of FIG. 1 with yet still another alternative embodiment of an indicator thereon;

30

FIG. 35 is a partial perspective, partial sectioned view of yet another embodiment of the present invention; and

FIG. 36-41 are cross sectional views of alternative embodiment of the present invention.

5 FIG. 42 depicts a partially sectioned top view of the a first preferred embodiment of a delivery apparatus of the present invention;

FIG. 43 depicts a partially sectioned, front view of the delivery apparatus of FIG. 35.

10 FIG. 44 is a partially sectioned side view of a second embodiment of the delivery apparatus;

FIG. 45 is a cross-sectional view of the locking handle of the apparatus of FIG. 39;

FIG. 46 is an alternate embodiment of the piercing cannula of the apparatus of FIG. 39;

15 FIG. 47 discloses a sectioned side view of a third embodiment of the delivery apparatus that includes a second syringe to pressurize and displace radioactive fluid from the source vial;

FIG. 48 discloses a sectioned side view of a fourth embodiment of the delivery apparatus that includes a second syringe to pressurize and displace radioactive fluid from the source vial;

20 FIG. 49-50 disclose sectioned side views of a fifth embodiment of the delivery apparatus with a locking slidable source vial housing; and

FIG. 51 discloses a sectioned side view of a sixth preferred embodiment of the delivery apparatus in which the source vial housing serves as a plunger for the discharge of radioactive fluid.

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Detailed Description

FIGs. 1 to 6 disclose one embodiment of medical radiation treatment delivery apparatus 10 of the present invention which includes a supply of radioactive fluid, preferably gas 12, and a radioactive fluid delivery system such as balloon catheter apparatus 20. Preferably, the balloon catheter apparatus 20 is made of latex or a similar synthetic compound, commonly used for intravascular applications,

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and void of any silicon-based or other metal-based materials. The balloon catheter apparatus is disposable after each patient use, and is designed to handle peak expected pressures less than those used in conventional angioplasty. These pressures typically range from one to ten atmospheres.

5 As used herein, the term "fluid" includes any gas, liquid, or gel-type substance that generally conforms to the shape of the container within which it is held, and is fluent. While the catheter apparatus of the present invention is used in conjunction with a radioactive carrier fluid, it is preferred that the fluid is a gas, and for reasons hereinafter set forth, an inert gas, such as preferably xenon, or an isotope
10 of xenon. A radioactive gas such as xenon in combination the at least one balloon section preferably provides a homogenous radiation delivery to the tissue to be treated. The lower pressure gas allows the balloon section to conform to or match with the tissue to be treated. However, the present invention is not limited to xenon gas or an isotope thereof, and the preferred fluid includes all gases and isotopes
15 thereof, radioactive gases or radiogases (inert and/or non-inert) or gases capable of fluorescence, phosphorescence, or luminescence (electron stimulation). Examples of gases include, but are not limited to, xenon, krypton, neon, radon and their isotopes. A radiogas can be dissolved in a liquid or solution (sterile) and be used as a liquid radiofluid. Liquids include all isotopes of liquids and solutions. An isotope
20 can be radioactive or non-radioactive. Radioactive includes nuclear (nucleus) decay of an atom. A radionuclide is any radioactive atom. Fluorescence, phosphorescence or luminescence is associated with electron instability and subsequent emission of radiant energy. Liquids also include all gasses dissolved in liquids or solutions. Examples of liquids include, but are not limited to, liquid phosphorus, rhenium,
25 yttrium, technetium, iodine, gallium, chromium, strontium, thallium, samarium, ytterbium, palladium, and all isotopes thereof, and all compounding and binding solutions thereof. All gels utilizing the aforementioned gases or liquids (solutions) are also contemplated. Additional radionuclides can include osmium, vanadium, ruthenium, bismuth, or other transitional heavy metals and their isotopes for liquid
30 and/or gel-type compounding. All inert dual photon/electron emitting radionuclides are further contemplated as well as all inert single particle radio-emitting nuclides and

all non-inert radionuclides thereof. Still further contemplated are all inert or non-inert radiofluids which use electron stimulation to produce by-product fluorescent, phosphorescent or luminescent radiant energy for patient treatment. The use of by-product radiant energy emissions including fluorescent, phosphorescent or luminescent emissions can be utilized for therapeutic treatment. Implementation of radionuclide and by-product radiant energy emissions can be applied by the use of the catheter apparatus in the following combinations;

(a) gases and/or fluids or single fluids alone either as a gas-gas or gas-liquid, and/or either inert or non-inert, and/or radioactive or non-radioactive such that the photon or electron emissions of one radiofluid can induce electron shift, scatter, or a quantum level change in the electron shell of the same or other combined "fluid" atoms thereby causing production of relatively low energy photon/electron (possibly in a cascaded amplification) emissions into the targeted tissue as a controlled/calculated dose;

(b) radiofluid(s) as described in (a), except that induction of listed radiant energy is provided via electrical source stimulation from an electrode, cathode, wire or other transmission source such that controlled electrical currents and/or electrical potential delivered through the catheter to the radiofluid or non-radiofluid of the balloon catheter which causes expected electron excitation and/or quantum level fluctuations with by-product fluorescence, phosphorescence and/or luminescence for the aforementioned therapeutic treatments; and

(c) phosphorus and/or other known fluorescent metals or alloys are implanted in the balloon material and/or catheter structure so that the combinations described in (a) and (b); radioemission, by-product decay energy and/or direct electrical stimulation can cause effect on the implanted/layered materials so as to create fluorescent, phosphorescent or luminescent energy delivery as these materials stabilize their electron structure after such stimulation.

The unique medical radiation treatment delivery apparatus 10 of the present invention uses a radioactive fluid. The catheter apparatus 20 includes a single balloon or a plurality of balloon sections 22, 24, and 26, which are inflated with the radioactive fluid. Residual blood flows through the vessel when the balloon

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or balloon sections 22, 24, and 26 are inflated through a plurality of interposed sections 32, 34, and 36 disposed between the balloon sections.

FIG. 25 depicts an enlarged, pictorial, proximal end view of a medical fluid delivery system such as catheter apparatus 20 of FIG. 1. Affixed, positioned, disposed, or connected to, on, or about the outer surface of catheter apparatus 20 near the distal end thereof is indicator 21, which is indicative of a radiation dosimetry unit of measurement 18. By way of example, radiation dosimetry unit of measurement 18 is at least indicative of the radiation that can be radiated through at least one portion of the catheter apparatus. The at least one portion of the catheter apparatus includes preferably a single balloon or balloon sections 22, 24, and 26, which are inflated with a radioactive fluid. The radiation dosimetry unit of measurement for the balloon or balloon sections of the catheter apparatus can include, but is not limited to, radiation dose rate, total radiation dose at a predetermined tissue depth, radiation source activity, radiation time exposure, tissue depth of a radiation dose, radiation source, or an incidental radiation dose rate. The total radiation dose at a reference tissue depth for a radioactive fluid delivery device such as catheter apparatus 20 is approximately equal to the radiation source activity (i.e., specific activity in millicuries per volume or density unit) multiplied by the radiation dose rate of the device multiplied by the exposure time of the radioactive fluid source. By way of example, a typical prescribed total radiation dose for a radiation delivery device such as catheter apparatus 20 can be 1400 cGy. This total radiation dose rate is referenced to a tissue depth at a delivery interface of typically .25 mm or .50 mm for a radioactive fluid such as Xenon 133 gas. A typical radiation dose rate for a balloon catheter of the present invention can typically be in the range of 2 to 10 cGy per minute per millicurie (mCi).

The radiation dose rate of a balloon material is a function of or is dependent upon the thickness of the balloon material, the density of the balloon material, and/or the volume of the balloon. In addition, the volume is, in turn, dependent upon the length of the radiation source and, in particular, the longitudinal length of the balloon along with the diameter and radius of the balloon. The axial length of the balloon is important with respect to the radiation source in that

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accumulative dosimetry effects (scatter, coincidence, photo electric) are achieved with the radioactive fluid disposed along the length of the catheter. The radiation dose rate is also effected by the surface area of the inflatable balloon in response to the radioactive fluid.

5 Radiation source activity is a function of the radioactive fluid or preferably of the radioactive gas that is used with the radiation treatment. As described hereinafter, radioactive Xenon 133 gas is preferred in that it is an inert gas that provides synchronous gamma and beta radiation emission with a half life of approximately five days. Concentrations of Xenon 133 gas can typically range from
10 10 mCi to 150 mCi per cc or more of gas volume at the time of calibration.

 Radiation exposure time is prescribed by the attending physician, commonly with a speciality in radiation oncology, nuclear medicine or nuclear oncology. Exposure times range from less than a minute upwards to ten minutes, depending on the activity of the radiation source. Particular concentrations of the
15 radiation source are normally provided with commercially available radiation sources. These concentrations are used by the physician to determine radiation exposure time. The radiation dose rate is a function of the properties of delivery devices such as catheter apparatus 20, which in turn is a function of balloon material thickness, density and volume as previously indicated. External or internal brachytherapy
20 medical radiation delivery apparatus can be experimentally dose calibrated and verified by a radiation physician specialist, medical physicist, or certified radio/nuclear laboratory, or with approved device-specific computer software for patient treatment. With such a calibrated radiation dose rate, the physician can calculate and prescribe the required radiation source concentrations and exposure times for treatment of the
25 patient. The calibration of the delivery device typically includes positioning the delivery apparatus in a phantom and positioning radiation detectors/sensors at a prescribed distance away from the delivery apparatus in the phantom. A series of measurements are used to graph the radiation from a series of radioactive fluid concentrations applied thereto. Such calibration is necessary and demanded by
30 various regulatory agencies so that the radiation treatment provided to a patient is

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within specified limits of the prescribed total radiation dose. In addition, multiple radiation safety profiles are evaluated for handling and delivery.

FIG. 26 depicts an enlarged, pictorial, proximal end view of catheter apparatus 20 of FIG. 1. In this particular embodiment, the radiation dosimetry unit of measurement 18 is the radiation dose rate, which is indicated as 10 cGy/min/mCi at a tissue depth of .25 mm for a radiation source of Xenon 133. With this radiation dosimetry unit of measurement indicated on the catheter, an attending physician can readily calculate and prescribe a desired total radiation dose for a patient with commercially available radiation concentrations of, for example, Xenon 133 and a calculated radiation exposure time as a verified standard for a particular catheter/balloon make, style, and size. As a result, the attending physician eliminates the need to perform more laborious calculations and independent measurements, or having the delivery device sent to a medical physicist or laboratory for calibration of the radiation dose rate of the delivery device.

In addition, the catheter is made in a uniform-single construct with a gas-tight injection port component, which is leak-proof and injection "friendly" and has a septum of "resistant" synthetic rubber (viton), which minimizes risk of leak or xenon adsorption. Furthermore, a leak-tight directional valve controls and locks direction of radio fluid passage for safety. A standard-type catheter would not provide this.

Although the indicator is affixed, positioned, disposed, connected to, on, or about the proximal end of the catheter for visualization by the attending physician, this indicator 21 is normally indicative of the portion of the delivery system such as the inflated balloon of a balloon catheter, which is inflated for the purposes of making contact with tissue to be treated. More particularly, the indicator and the radiation dose rate is indicative of the material that comes in contact with the tissue to be treated. By way of example, the outer surface or wall of the balloon catheter along with the density and thickness thereof are one of the major factors in determining the radiation dose rate. This radiation dosimetry unit of measurement is experimentally calculated or computer modeled and verified with experimental calculations and applied preferably to the proximal end of the delivery system. The indicator of the

dosimetry unit can be printed or painted on the outer surface of the catheter, embossed in or raised from the outer surface of the delivery system. The indicator can comprise at least one of a plurality of symbols, letters or numbers disposed on the radioactive delivery system for indicating the dosimetry unit of measurement. It is also contemplated that any indicator of whatever type can be affixed, disposed or positioned on the delivery system for the purposes of indicating at least one radiation dosimetry unit of measurement. Not only can the radiation dosimetry unit of measurement be directed to the portion of the delivery system that comes in contact with the tissue to be treated, but also radiation indicators such as incidental radiation dose rate, which is important to attending personnel to minimize their exposure to radiation.

FIG. 27 depicts an enlarged, pictorial, proximal end view of catheter apparatus 20 of FIG. 1 in which the radiation dosimetry unit of measurement 18 is indicated as total dose and, in particular, a total radiation dose of, for example, 1400 cGy. This indicator 21 is thus printed, embossed, or raised and indicated as total dose. Inflation lumen 23 extends longitudinally through elongated member 29 of catheter apparatus 20. A gas tight fitting/hub 30 is affixed in a well-known manner to elongated member 30 of catheter apparatus 20. These particular components of catheter apparatus 20 are also depicted in FIGS. 25 and 26. Elongated member 29 comprises a polyurethane, polyethylene, polyimide, polyvinyl chloride, polyamide, polytetrafluoroethylene, silicone, or any other suitable material. The selection of the catheter material is typically dependent on the particular anatomical site that the catheter apparatus is to be positioned or extended through. These elongated member materials can also be coated with a hydrophillic slip coating to further ease insertion and introduction to the treatment site. In addition to well-known hydrophillic slip coatings, the inner and/or outer surfaces of the elongated member can be treated such as with ion beam bombardment or deposition, which is commercially available from the Spire Corporation, Bedford, MA. Ion beam bombardment or deposition can significantly alter the surface energy density of the elongated member material to reduce adhesion of thrombus or other agents thereon. This treatment is also known to provide an antibacterial, antifungal, or an antithrombogenic surface.

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To minimize radiation exposure to attending personnel elongated member 29 of catheter apparatus 20 can include a high density material to absorb and/or block the radiation from the radioactive fluid when in inflation lumen 23. By way of example, this high density material can constitute a loading of greater than 30 percent by weight of, for example, barium, tungsten, lead, tantalum, titanium, bismuth, gold, platinum, palladium or rhodium.

Referring the reader's attention to FIGs. 1-4 and 6-8, the portion of the delivery system such as balloon 22 through which radiation from a radioactive fluid is normally directed includes at least one of silicone, latex, a synthetic material similar to latex, polyamide, vinyl, polyethylene, polytetrafluoroethylene, polyethylene terephthalate, fluorinated ethylene propylene, or any other suitable material. The balloon material can also include a loading of high density material to absorb or block radiation and thereby consequentially redirect the radiation to the treatment site. This material can also block or lessen radiation exposure of blood passing through the balloon sections. This high density material can be a loading of greater than 20 percent by weight of at least one of barium, tungsten, lead, tantalum, titanium, bismuth, gold, platinum, palladium or rhodium. The radiation dose rate of the balloon can also be altered or redirected by applying a thin coating of a metal or other reflecting materials to the various inner and outer surfaces of the balloon as herein later described.

FIG. 28 depicts an enlarged, pictorial, proximal end view of catheter apparatus 20 of FIG. 1 with an alternative embodiment of indicator 21 affixed, disposed or positioned thereon. Indicator 21 includes a housing or holder 19 as depicted in which a radiation sensitive film 31 is positioned therein. The arrow indicates the placement of radiation sensitive film 31 into indicator holder 19. Positioned adjacent to aperture 33 on the indicator is a visible shades scale 35 having various shades of gray between white and black at the opposite ends thereof. When exposed to various dosages of radiation, radiation sensitive film 31, such as a Gafchromic type film from, for example, Nuclear Associates of Carle Place, N.Y., changes color. The Nuclear Associates' Gafchromic film exhibits various hues of blue in response to radiation. This change in color is visible as a change from clear

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to black with various shades of gray therebetween. The various shades of gray or blue indicate the amount of radiation that film 31 has been exposed to. Thus, the attending physician can readily match the visible shade of radiation sensitive film 31 with gray scale 35 to determine the radiation dose and activity of the radiation source. For purposes of convenience, total dose amounts can be printed or indicated right next to each shade of gray on gray scale 35.

FIG. 29 depicts an enlarged longitudinal sectioning of elongated member 29 of catheter apparatus 20 through indicator 21. Radiation sensitive film 31 is inserted into channel 37 of the indicator for visual reading of the change in color of the film. The bottom material 39 of indicator 21 is preferably selected to be that of the material coming in contact with the tissue to be treated. Even more preferably, the bottom material is selected to be of equal thickness along with the same loading of the high density material of the balloon material. This is to best approximate the radiation dose being applied through the balloon to the treatment site. Depending on the radiation volume size, the thickness and loading of the bottom material can be modified to more closely approximate the total radiation dosage being radiated at the treatment site.

FIG. 30 depicts an enlarged sectional view of an alternative embodiment of radiation sensitive film 31. In this embodiment, the radiation sensitive film is layered in a stair step configuration to provide a greater change in color or the gray scale depending on the type of radiation source being utilized.

FIG. 31 depicts still another alternative embodiment of radiation sensitive film 31 in which strips of radiation sensitive Gafchromic type film are butted end-to-end. Each strip or segment has a different sensitivity to radiation and thus can be utilized to indicate a much larger range of radiation doses being exposed thereto.

FIG. 33 depicts an enlarged, sectioned, proximal end view of catheter apparatus 20 of FIG. 1 with still another alternative embodiment of radiation indicator 21 thereon. In this particular embodiment, radiation indicator 21 includes radiation sensitive film 31 positioned around elongated member 29 of the catheter. The thickness of elongated member 29 underneath radiation sensitive film 31 is formed to approximate the relative thickness of the balloon catheter as well as the treatment

depth of the tissue intended to be in contact with the balloon. As a result, the wall thickness of member 29 beneath radiation sensitive film 31 best approximates the balloon material and tissue so that the radiation sensed by film 31 is that at the desired tissue treatment depth. The Xenon radioactive gas resides in inflation lumen 23 of the elongated member as well as the inflatable balloon. Positioned over and around radiation sensitive film 31 is transparent material 49 such as clear silicone so as to hold the radiation sensitive film in position around the proximal end of the catheter apparatus. The clear transparent property of this material or other similar materials provides for minimal distortion of the hue or color of the radiation sensitive film.

FIG. 34 depicts an enlarged, sectioned, proximal end view of the catheter apparatus 20 of FIG. 1 with yet still another embodiment of indicator 21 disposed thereon. In this particular embodiment, the radioactive fluid not only passes through inflation lumen 23 of elongated member 29 but also out of side port 43 to electronic radiation detector 41. This electronic radiation detector is commercially available and is an electronic ion exchange detector. Electrical conductor leads 42 extending from the radiation detector are connected to an electronic display unit such as an LCD or LED display for displaying radiation level(s).

Returning the reader's attention to FIGs. 1-6, the method of the present invention is designed to apply ionizing radiation prophylactically to post-angioplasty vascular tissue or tumors disposed internally within a patient while minimizing exposure of healthy tissue. Initially, the location and the size of the lesion 40 to be treated are clinically identified, perhaps, with a fluoroscope. The catheter apparatus 20 is then introduced and positioned adjacent to the lesion 40. The plurality of discrete balloon sections 22, 24, and 26 of a special, hypo-dense, thin material enable the inflated catheter apparatus 20 to more closely match and/or conform with the internal tissue wall, and minimize the amount of internal gas loss in the event of leakage. The catheter apparatus 20 includes an outer retractable radiation sleeve or shield 50 to prevent the exposure of healthy tissue adjacent to the lesion to radiation. After the catheter apparatus 20 is positioned alongside the lesion 40, the radiation shield 50 is retracted to a specific measurable length as depicted in FIG. 32. This

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specific length controls dosage rate and radiation source volume size. The balloon sections 22, 24, and 26 are then inflated with the radioactive fluid exposing the lesion 40 to the radiation dosage. The preferred gas, xenon or xenon isotope, emits beta and gamma particles into the lesion 40. Furthermore, indicator 21 can be used to establish dosage rate and total radiation dose.

The catheter apparatus 20 enables substantial blood or other fluid flow between the balloon sections 22, 24, and 26 when fully inflated. The balloons sections 22, 24, and 26 include a unique inner and outer surface 25 and 27 configuration. The radiation flow is directed through the outer surface 27 of the catheter apparatus 20 to the lesion 40 while exposure to radiation of the blood flowing internal to the catheter apparatus 20 is minimized. Accordingly, the inner surface 25 is more attenuating to the transmission of radiation than the outer surface 27. Either the inner surface (wall) 25 is thicker than the outer surface (wall) 27 as shown in FIG. 7, or the inner surface 25 includes a layer of material that is resistant to the penetration of radiation (not shown).

When a multiple balloon system is used, preferably either three discrete balloon sections are used as shown in FIGs. 1 through 6, or four balloon sections 22, 24, 26, and 28 with interposed sections 32, 34, 36, and 38 can be used as shown in FIGs. 9 and 10.

One primary application of the system of the present invention is for use after standard, angioplasty procedure: including multiple lesions at one treatment session. Controlled internal radiation therapy is provided to an artery or vessel for the prevention of arterial restenosis due to smooth muscle hyperplasia or similar related pathology. This will enable cannulation via the same access port from the preemptive dilatation procedure.

Discrete balloon sections or segmented systems 22, 24, and 26 or possible variants thereof are specifically structured to enable the application of a radioactive gas for therapeutic intent.

FIGs. 11 through 16 disclose another embodiment of catheter apparatus 120 of the present radiation delivery device invention. Drafted segmental and peripheral "tire-like" balloon sections or segment configurations 115 optimize direct

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circumferential abutment of the entire lumen wall. This will minimize intraluminal attenuation factors and maximize homogenous dose rate delivery, conforming and enabling irregularly-shaped intimal surfaces. Also, when the catheter segments 115 are pressurized and expanded, a significant residual rate of intraluminal blood flow is enabled internal to the segments.

The catheter apparatus of the present invention is designed to minimize the secondary risk of medical complications caused by blood flow deficiency due to underlying disease or vasospasm in the peripheral, kidney, and, particularly, the heart vessels. The centrally directed perfusion flow can also contribute to outwardly directed pressure gradients, therefore, further supporting and stabilizing the radioactive-gas expander balloons against the arterial wall.

The catheter apparatus of the present invention enables individual patient flexibility as to dosage, treatment exposure time, and lesion segment lengths. Also, since blood flow cannot be completely occluded during therapy, radiation time need not be limited to less than three minutes, and therefore, very high energy gamma emitters or radiation activity levels are not needed. More expensive loading devices, shielded treatment rooms, and solid radio sources are thereby avoided. Also, healthy tissue is not unnecessarily exposed to passing or placement-preparation time irradiation as with other solid-source systems.

If inadequate blood flow rates or distal symptoms occur, this closed, sealed and inert radioactive gas system 10, 110 can be easily deflated without exposing the patient or medical personnel to real radiation risk. After flexibly allowing for several minutes of reperfusion time, the catheter apparatus 20, 120 can be simply reinflated and the prescribed treatment time/dose (several times if needed) is resumed without diminishing the therapeutic benefit.

Furthermore, the system of the present invention enables the treating therapeutic radiologist to address more than one vessel system or lesion even distal to the distribution of the primary lesion that may require subjective variation in post-dilatation balloon length and diameter due to sensitivity of distal ischemic-prone tissue from risk of prolonged diminished blood flow.

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The sectioned, segmented or compartmentalized radioactive gas delivery tracks communicating with the end point expander balloons, will minimize the potential volume of gas leak should a balloon lose integrity. The residual catheter gas volume may be withdrawn into the shielded syringe without further leakage. The bloodstream released gas poses no real radiation or chemical threat to the patient, because of the physical and biological properties of the inert gas.

The length of the distal expandable component of the catheter apparatus 20 or 120 is covered by a thin, retroslidable or static sleeve 50 or 150, as shown in FIGs. 4 and 16, which is radiopaque for purposes of imaging localization. The sleeve 50 or 150 is in direct continuity with and manipulatable externally by the physician. The sleeve is positioned proximal to the access port to the balloon sections or segments. After confirmation of placement of the distal catheter apparatus 20 or 120 by fluoroscopic means, the catheter sleeve 50 or 150 is slowly pulled back, and a concordant ruler is exposed in parallel, measured in millimeters, whereby the treating physician accurately determines the length of the balloon to be expanded, and the length of the vessel wall to be treated 40 or 140. Alternatively and preferably, indicator 21 can be utilized to establish selectively the dosage rate as illustrated in FIG. 32. This will enable immediate confirmatory calculations as to specific dose rates, treatment time, and the volume of the radioactive gas injected.

The proposed radioactive gas or gases emit gamma photons enabling imaging and semi-log calculations to be performed at bedside using a conventional gamma camera and computer (not shown), which is left on the monitor distal to the treatment field to detect any early leakage for concerned physicians at minimal additional cost.

Although the lumen diameter is narrow and contains only a small fraction of the total volume of radioactive gas injected per session, the designed shielding properties of the sleeve 50 or 150 or outer lumen wall layer minimize any significant normal tissue or blood cell exposure over the remaining non-inflated catheter length, particularly with the energies of emission of the isotopes selected.

The interval and possibly staggered placement design of the entry portals and columns between the catheter body and expansion "modules" or balloons enable

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cutoff control of the balloon expansion length due to the controlled length of outer sleeve retraction.

The primary rationale and benefits for the therapeutic application of radioactive xenon gas with the "ASP" or similar catheters for intravascular brachytherapy enable precise determination of total dose, dose rate, and depth distribution of radiation emitted from a source.

Radioactive Xenon-133 gas, and less commonly used Xenon-127 gas and krypton 85, as well as, technetium compounds, have been widely used for several years and proven relatively safe within medically accepted radiation levels for nuclear diagnostic studies involving the lung and the measurement of blood and fluid flow rates through vessels to specific organs. When used as an unsealed free-gas form, the inert, noble gas properties essentially enable the molecules to rapidly dissipate throughout the body of the patient or through a room, without any prolonged organ accumulation or interaction within specific dose ranges. Rapid expulsion of the relatively lower energy nuclear emissions of the xenon, is quickly re-released from the bloodstream through the lungs.

Xenon is a very stable element which can be pressurized, stored, and made to high millicurie activity per cubic centimeter (cc) with very reasonable cost and availability.

Xenon-133 provides both a beta particle (101 kev avg.; 364 kev max.), and at least two usable photons (32 kev 48 percent; 81 kev 37 percent).

The beta particles offer excellent initial dose rate delivery when directly adjacent to the tissue with the first millimeter. The particle does not penetrate much beyond the first millimeter of tissue, thereby not contributing to any significant distal normal tissue exposure.

The gamma photon energies and their decay fractions provide complementary dose deposition for the first millimeter, and primary dose delivery for an additional several millimeters of arterial wall and adjacent tissue. The high percent of attenuated, and lower energy photons beyond this point provide for ease of personnel protection with routine lead jackets, or by placing a cover over the external

surface of the treated region. Furthermore, the sensitivity of a small field gamma camera provides simple image monitoring and dose evaluation simultaneously.

Xenon-133 is commercially available within a week in concentration ranges from 10 mCi to 150 mCi per cc or more of gas volume. Also, the cost is currently estimated to be less than a few hundred dollars a dose of 150 mCi. A single dose order can be used to treat several patients per day for a full week, as the physical half-life is 5.2 days. Also, no special equipment, storage, or delivery devices are necessary, except for routine facilities available in most nuclear medicine or radiation oncology departments.

In vivo and *in vitro* facilities with standard exhaust hoods or negative pressure rooms provide adequate protection for this sealed use of xenon gas. A metered dose can safely and readily be transported to nearly any treatment site by one person, and administered by one person without special radiation protection needs, such as is necessary with higher energy photon sources for conventional brachytherapy. The most expensive addition to a standard treatment room is a simple negative pressure ventilation system, as a backup safety mechanism.

Selective balloon shapes and designs with various thicknesses and pliable lucent and radio penetrable materials enable site specific, intracavity or intraparenchymal insertion and localization from external origin and placement. FIGs. 17, 18, and 19 illustrate various other applications for catheter apparatus 220 which can include brain, lung, esophagus, trachea, cervix, biliary ductal system, colon or rectum, the gastrointestinal system, the gynecological system, and head and neck. All can optimize the self-introduction of radioactive -133 or others, with controlled expansion and dose rate delivery while enabling individual tissue compliance such that the entire tissue is immediately and homogeneously adjacent to this high or low dose rate source without requiring surgical implant disruption, patient isolation, use of high energy concentrations of other radio nuclides, patient or medical personnel risk from leakage, expensive materials, or costly radio-safe suite facilities.

The compliance, stress, and thickness properties of the balloons enable adequate and complete volume expansion against the variable surface of the arterial wall at less pressure than conventional therapeutic dilation plasty catheters.

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inflated and delivering treatment dosage, the opposing balloon is deflated 354. The support displacers 362 and 364 are juxtaposed against the vessel wall enabling blood to flow more easily through the space opposite to the treatment side.

5 The single-unit injection port 360 with synthetic septum is fluid-tight and leak-proof. The port 360 is preferably made of viton rubber, enabling easy needle penetration without loss of gas under pressure via leaky adaptive Luer-lock additions.

The radioactive xenon gas can be partially dissolved in sterile saline or lipid-containing solution for solubilizing the xenon. The resulting material can then be injected into a balloon system.

10 It is also contemplated that the dosimetry unit of measurement indicator 21 disposed, affixed, or positioned on a delivery device can be an electronic display panel such as LCD or LED. The display panel indicator can be connected to an electronic radiation sensor or detector positioned at that portion of the device for treating tissue. Such displays and detectors are commercially available.

15 Still another embodiment of catheter apparatus 400 is depicted in FIG. 35. A single angioplasty-style balloon 401 is mounted about the distal end 404 of the catheter 400. The balloon, which typically is under slight negative pressure just prior to treatment, is inflated with radioactive fluid that travels through inflation lumen 402 and enters the balloon at inflation port 403. In this embodiment, the inflation lumen
20 402 is made much smaller than in a typical balloon catheter 400 in order to minimize the amount of radioactive fluid in the catheter during treatment. This has the advantage of reducing potential exposure to the operator and non-target tissue of the patient, as well as reducing the amount of the costly radioactive source material needed to achieve the desired dosimetry at the treatment site. The size of the
25 inflation lumen 402 is primarily limited by the tooling required to form the small lumen, typically, but not limited to approximately .010" in diameter. Radiopaque markers 405, 412 positioned near the proximal and distal ends of the balloon 401 aid the operator in placement of the balloon 401 under fluoroscopy. An alloy of tungsten and iridium makes an excellent radiopaque material, but almost any
30 biocompatible radiopaque material can be used. The catheter 400 further includes a second lumen 406 through which a wireguide 407 can be introduced to assist in

placement of the balloon 401 at the treatment site. The wireguide lumen is sufficiently large (typically over .020" in.) to accommodate a standard coronary wireguide. The wireguide 407 exits the catheter 400 through an orifice 408 at the catheter's distal end 404.

FIGs. 36-41 depict alternative methods of providing shielding to protect the patient and/or operator from radiation outside of the intended balloon source. FIGs. 36-38 are cross-sectional views of the catheter embodiment of FIG. 35, while FIGs. 39-41 represent cross-sectional views of a catheter embodiment similar to FIG. 35, except lacking the second larger guidewire lumen 406. FIGs. 36 and 39 depict a catheter 400 that has been loaded with a high density shielding material 409 including, but not limited to barium, tungsten, lead, tantalum, titanium, bismuth, gold, platinum, palladium, rhodium, or any other similar suitable material, or a combination thereof. A load of 20% barium sulfate, provides good shielding properties and excellent radiopacity without comprising the integrity of the catheter. Much higher amounts of shielding material can cause failure of the bonds between the balloon material and the catheter. FIGs. 37 and 40 depict catheters 400 that have had shielding added by the addition of a layer 410 of metal ions that have been deposited on the outside surface of the catheter 400 by a technique such as ion beam deposition (Spire Corp., Bedford MA). Another method of producing such a layer would be to shrink or bond a plastic film containing metal ions to the outer surface of the catheter 400. FIGs. 38 and 41 depict catheters 400 that are shielded by a outer sleeve or guiding catheter 411 which is loaded with a shielding material such as barium sulfate. Since bonding is not applicable for a such a sleeve, the amount of metal added to the plastic can be higher than that for the balloon catheter 400. The shielding sleeve 411 can comprise the entire length of the catheter (leaving the balloon portion exposed), or can be used only on the portion of the catheter that is outside the body in order to protect the operator handling the delivery system.

Fig. 42 depicts a partially sectioned top view of a medical radiation treatment delivery apparatus 1400 of the present invention. The delivery apparatus 1400 basically includes a radioactive gas vial enclosure, such as source vial housing

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1403; a selector mechanism such as a multiple position valve 1409, and a gas-tight, variable volume chamber such as a gas-tight syringe 1411 interconnected as depicted by passageways, lines, connectors, ports, or cannula 1406, 1408, 1412, 1413, 1415, 1417-1421, and 1424 to radiation delivery balloon catheter 1422. A
5 commercially available fluid pressure gauge 1414 is positioned between cannula 1415 and 1417 using for example, a well-known connector 1418. Multiple position valve 1409 and, preferably, four-way valve 1409 is interconnected between connector 1408 and 1420, cannula 1415 and vacuum line connector 1424. Valve 1409 includes a selector knob 1421 to interconnect main cannula 1415 selectively
10 to vial connector 1408, catheter connector 1420, and vacuum line connector 1424. Delivery apparatus 1400 includes valve gauge housing 1427 for housing the pressure gauge and the four-way valve along with the associated previously described lines, connectors, ports, or cannula within chamber 1428. As a safety feature, an additional vacuum line 1425 is attached to secondary vacuum line 1426 for
15 evacuating any radiation fluid from within chamber 1428. A primary vacuum line 1423 is connected to the multiple position or four-way valve 1409 for evacuating radiation fluid via the valve 1409. In order to provide additional safety for the operator and patient, the outer housings material of the delivery apparatus may also include a high density material of at least one of barium, tungsten, lead, tantalum,
20 titanium, bismuth, gold, platinum, palladium, rhodium, or any other similar suitable material for shielding from beta and gamma particles emitted by the radioactive source material. This shielding material may incorporated into the plastic housing and/or comprise a lining or chamber enclosing the source vial or delivery syringe.

Delivery apparatus 1400 further includes source vial chamber enclosure
25 1403 such as housing 1403 attached to valve gauge housing 1427. Included in the source vial chamber housing 1403 is source vial chamber 1402 for positioning source vial 1401 therein. The source vial enclosure 1403 includes a enclosing means 1404 that permits loading of the gas vial into the chamber and also serves to seal the enclosure 1403 to prevent gas leakage. Extending from vial connector 1408 is well-
30 known piercing cannula 1406 extending into chamber 1402. A source vial 1401 is positioned in chamber 1402. The source vial includes a radiation fluid such as, but

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not limited to, Xenon 133 gas therein for delivery to an external device 1422, such as a balloon delivery catheter 1422. The source vial 1401 is inserted in chamber 1402 and urged toward piercing cannula 1406 via an urging mechanism 1442 such as a threaded chamber cap 1482, which comprises the enclosing means 1404 for the gas vial enclosure and the maintains a gas-tight seal for chamber 1402. In the illustrative embodiment, urging mechanism 1442 such as a threaded chamber cap 1404, is threaded into the chamber. The inner surface of the urging mechanism 1442 contacts the vial 1401, which is urged forward to contact the fixed piercing cannula 1406. The piercing cannula 1406 extends through the vial septum 1407 of source vial 1401 for establishing communication with the radiation fluid contained therein. The source vial septum 1407 is urged forward to one end of the vial chamber 1402 to engage O-ring 1405 to maintain a gas-tight seal. Should any radioactive fluid escape the vial 1401 and enter chamber 1402, communication channel 1429 extending between chambers 1402 and 1428 permits secondary vacuum line 1425 attached to the secondary vacuum port 1426 to scavenge the fluid therefrom.

Delivery apparatus 1400 also includes syringe housing 1416 connected to valve-gauge housing 1427. A gas-tight syringe 1411 is positioned in syringe housing 1416 and connected to the syringe to pressure gauge cannula 1417. Communication channel 1430 communicates with air space 1432 and 1436 for evacuating any radioactive gas or fluid that escapes the syringe 1411. Secondary syringe communication channel 1431 interconnects air space 1432 and 1436. Syringe housing 1416 is enclosed at one end with threaded collar 1441 through which well-known and commercially available threaded advancing mechanism 1438 connected to handle 1439 and thread release mechanism 1440. Opening 1437 around advancing mechanism 1438 allows air to be drawn into the syringe housing to permit evacuation of escaped radioactive fluid. At the other end of the housing is syringe barrel 1434 in which syringe plunger 1433 is positioned. Well-known O-ring 1435 is positioned at the proximal end of the plunger to maintain a gas-tight seal.

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The syringe plunger 1433 is used to evacuate fluids such as air or radiation fluid from the delivery catheter when the multiple position valve 1409 is appropriately positioned. The gas-tight syringe 1411 and plunger 1433 are also used to evacuate and return air or radiation fluid to and from the source vial 1401, the vacuum line 1425 or the delivery catheter 1422 with appropriate selection of the multiple position valve.

The method for using the radiation treatment delivery apparatus 1400 involves placing a radiation source vial 1401 within a source vial chamber 1402 thereof, which is then sealed. The source vial 1401 is advanced using an urging mechanism 1442, such as a threaded cap 1482, until the septum 1407 of the vial 1401 is pierced by a needle piercing cannula 1406 connected to a multiple position valve 1409, such as a four-way valve. This step can be done by a technician or support personnel prior to bringing the apparatus 1400 to the actual treatment site. Prior to treatment, the apparatus is attached to a radiation delivery device such as a balloon catheter 1422. The vacuum line ports 1424, 1426 of the apparatus are connected to a scavenger system. Treatment is initiated with the catheter passageway 1419 which leads to the catheter 1422, being selected and the plunger 1433 of the syringe 1411 being withdrawn to evacuate air from the balloon catheter 1422 attached to the apparatus. The multiple position valve 1409 is then switched to the primary vacuum line 1423 and the air from the syringe 1411 is discharged into a commercially available radioactive gas scavenger unit. The multiple position valve 1409 is then positioned to passageway 1406 and source vial 1401, and the syringe 1411 is loaded with the radioactive gas. To treat the patient, the multiple position valve 1409 is positioned to the catheter passageway 1419, and the syringe plunger 1433 is advanced, preferably using a threaded advance mechanism 1438, until the radioactive gas is completely transferred from the syringe 1411 to the catheter 1422. After the prescribed dosage period, the radioactive fluid is evacuated into the syringe 1411. The multiple position valve 1409 is then positioned to passageway 1406 and source vial 1401, and the gas is returned to the source vial. The multiple position valve 1409 is switched to the vacuum line 1423 to evacuate some of the remaining gas in the system.

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FIG. 43 depicts a partially sectioned front end view of injection apparatus 1400 of FIG. 42. This particular figure illustrates the interconnection between the multiple position valve 1409 and pressure gauge 1414 via the gauge to valve cannula 1415 and connector 1413 that attaches at the syringe port 1412 located in this particular embodiment at the underside of the multiple position valve 1409. Primary and secondary vacuum line connectors 1424 and 1426 are also depicted with respect to the multiple position valve 1409 and valve-pressure gauge chamber 1428.

FIG. 44 is a partially sectioned side view of a second embodiment of the injection apparatus 1400 of the present invention. The apparatus includes a system for extracting a radioactive fluid such as Xenon 133 gas from a source vial 1401 by drawing the fluid into a gas syringe 1411 under negative pressure, where it is then injected into an external device such as delivery catheter 1422 depicted, for example, in FIGs. 1-41. As a safety measure, the apparatus can be attached to a well-known scavenger system to carry away any radioactive fluid that remains in the apparatus following treatment or that might leak from or around one of the connections or seals. The components of the radioactive fluid injection apparatus are integrated within an outer housing 1452 that helps shield the user from radiation.

The radiation fluid source vial 1401 is loaded into the apparatus by removing the threaded vial chamber cap 1482 of radioactive gas vial enclosure 1403 and placing the source vial 1401 in the source vial chamber 1402. A plunger 1444 is slidably attached to the cap that receives the bottom end of the source vial when the vial is within the chamber. A locking handle 1443 on the shaft 1456 of the plunger, as shown in a cross-sectional view in FIG. 45, is rotated around the shaft 1456 to a position that allows the plunger to be advanced using the external handle 1446. The source vial 1401 is advanced within the source vial chamber 1402 until a piercing cannula 1406 pierces the septum 1407 of the vial. Piercing cannula or passageway 1406 supplies radioactive gas from source vial 1401 to an external device such as a balloon catheter 1422. A spring 1445 attached about the shaft 1456 of the plunger provides tension against the source vial 1401 to hold the vial in place. An alternate embodiment of the piercing cannula 1406 as depicted in FIG. 46. In this embodiment, the piercing cannula is protected by a plastic sheath 1462

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held in place by an attached spring 1449 that compresses with the advancing source vial 1401, forcing back the sheath 1462 and allowing the exposed tip of the cannula a passageway to puncture the vial septum.

Returning to FIG. 44, any leakage of radioactive fluid between the piercing
5 cannula 1406 and septum 1407 is drawn from the source vial chamber 1402 via one or more vacuum ports 1450 that attach to a standard radioactive gas scavenger system. After the source vial 1401 has been punctured by the piercing cannula 1406, the multi-position valve 1409 is positioned so that the source vial 1401 communicates with the gas-tight, variable volume chamber such as syringe 1411.
10 The radioactive fluid in the source vial 1401 enters the gas syringe 1411 when the syringe plunger 1433 is withdrawn using the external handle 1439. A double seal on the head 1472 of the plunger 1433 helps prevent leakage of the fluid into the air space 1436 between the plunger and the syringe housing 1416. Any fluid that leaks into this air space 1436 is aspirated through the vacuum port 1451 into a standard
15 external radioactive gas scavenger system. In the illustrated embodiment, a enclosure sealing mechanism 1447, such as a threaded cap 1447 is used to enclose the syringe chamber housing 1416. An O-ring 1448 provides a seal between the syringe chamber housing 1416 and the threaded cap 1447.

Once the gas-tight syringe 1411 has been loaded with radioactive fluid,
20 the multiple position valve 1409 is positioned to passageway or cannula 1419 to allow communication between the gas-tight syringe 1411 and the radioactive fluid delivery catheter 1422. A connector 1421 is located at the distal end 1490 of the injection apparatus 1400 to which the delivery catheter 1422 is attached. In the illustrated embodiment, a threaded coupler 1475 attaches to the connector 1421
25 which is also threaded. The air space 1474 created within the coupling after it is attached to the catheter communicates with a vacuum channel 1473 that leads to the outgoing vacuum line 1423. Treatment consists of discharging the radioactive fluid in the syringe 1411 into the delivery catheter 1422 for a prescribed period of time to provide a therapeutic radioactive dosage to the target site. During delivery
30 of the radioactive fluid, a pressure gauge 1414 is provided to monitor the pressure of the fluid leaving the injection apparatus 1400. After the prescribed period, the

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syringe plunger 1433 is withdrawn and the radioactive fluid is returned to the syringe 1411. The multi-position valve 1409 is then switched to the source vial position and the radioactive fluid is discharged back into the original source vial 1401. The final step consists of disengaging the source vial 1401 and piercing cannula 1406 to aspirate any radioactive fluid remaining in the system.

FIG. 47 discloses a sectioned side view of a third embodiment of the injection apparatus 1400 that includes a second syringe 1457 to pressurize and displace radioactive fluid from the source vial 1401. A selector mechanism such as multi-position valve 1409 is positioned for communication between a gas-tight, variable volume chamber such as primary syringe 1411 and the source vial 1401 via passageway or cannula 1406. The secondary syringe 1457 containing an inert fluid is discharged into the source vial via an inlet cannula 1454 that has pierced the septum 1407 of the source vial 1401. The inert fluid fills the space 1455 inside the source vial and displaces the radioactive fluid which is then forced through the outlet piercing cannula 1406 and into the primary syringe 1411. The multiple position valve 1409 is then selected for communication between primary syringe 1411 and the delivery catheter 1422, and the primary syringe 1411 is deployed for treatment. After the gas is withdrawn back into the primary syringe 1411, the multiple position valve 1409 is switched back to permit communication between the primary syringe 1411 and the source vial 1401 into which the remaining gas is returned.

FIG. 48 discloses a sectioned side view of a fourth embodiment of the injection apparatus 1400 that includes a second syringe 1457 to pressurize the gas vial enclosure chamber space 1402 at one end of the source vial 1401 to advance the vial within the enclosure chamber such that the cannula pierces the septum 1407 of the vial. The gas is drawn into a gas-tight, variable volume chamber such as primary syringe 1411 and discharged into the catheter 1422 in a manner similar to the embodiment of FIG. 48.

FIG. 49 discloses a partially sectioned side view of a fifth embodiment of the injection apparatus 1400 that includes a gas-tight, variable volume chamber such as syringe 1411 to pressurize and displace radioactive fluid from the source vial 1401 which is contained in vial enclosure 1403, into catheter 1422. A pressure

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gauge 1414 indicates the pressure measured within the internal space 1460 of the syringe. The inert fluid within the primary syringe 1411 is discharged into the source vial via a passageway such as inlet cannula 1454, displacing the radioactive fluid which exits the vial through the outlet cannula 1406 into the catheter 1422. In this embodiment, a safety hinged latch 1458 must be manually displaced to allow a slidable housing 1461 containing the source vial to advance and allow the vial to enter the lower source vial chamber 1402 of enclosure 1403 where the septum 1407 is pierced by the cannulae 1406, 1454. As an additional safety feature, a tab 1476 on the slidable housing engages a catch on the main housing 1452 to maintain the source vial 1401 in the delivery position throughout treatment.

Still an additional or alternative safety feature is depicted in FIG. 50. A vacuum-operated safety latch 1478 prevents the slidable housing 1461 from advancing until a vacuum on the source vial chamber 1402 deploys the safety latch 1478, pulling it inward, to allow the slidable housing 1461 and source vial 1401 to advance into position. The vacuum is created within the source vial chamber 1402 via a channel 1479 leading from the main vacuum line 1423.

FIG. 51 discloses a sectioned side view of a sixth embodiment of the injection apparatus 1400. In this embodiment, the source vial 1401 is placed within gas vial enclosure 1403 that is sealed with a threaded cap 1482. The chamber housing 1403 encases a multiple position valve 1409 that controls the flow of radioactive fluid from the vial to a gas-tight, variable volume chamber such as fluid chamber 1481 within the apparatus. An external knob 1483 controls the position of the valve 1409. The chamber housing 1403 and cap 1482 act as a plunger within the main housing 1452 to compress the fluid chamber 1481 containing the radioactive fluid and discharge the fluid through a passageway such as outlet channel 1419 into delivery catheter 1422.

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Claims

1. 1. A radioactive gas injection apparatus (1400), comprising:
a radioactive gas vial enclosure (1403); and
a first passageway (1406) for supplying radioactive gas to an external device (1422);
5 characterized in that said radioactive injection apparatus further comprises:
a gas-tight, variable volume chamber (1411, 1452);
a second passageway (1415, 1417, 1419, 1454) communicating with at least one of said radioactive gas vial enclosure (1403) and said gas-tight, variable volume chamber (1411); and
10 a selector mechanism (1409, 1461) interconnecting said second passageway with at least one of said gas-tight, variable volume chamber (1411), said radioactive gas vial enclosure (1403), and said first passageway (1406).
- 15 2. The radioactive gas injection apparatus of claim 1 characterized in that the radioactive gas vial enclosure (1403) comprises a gas-tight, radioactive gas vial enclosure (1403-1405, 1442-1446, 1456-1457, 1461).
- 20 3. The radioactive gas injection apparatus of claim 1 characterized in that the apparatus and/or radioactive gas vial enclosure (1403) further includes a radioactivity shielding component (1481).
- 25 4. The radioactive gas injection apparatus of claim 1 characterized in that the radioactive gas vial enclosure (1403) includes an urging mechanism (1442-1446, 1456-1457, 1461).
5. The radioactive gas injection apparatus of claim 4 characterized in that the gas vial urging mechanism (1442) includes at least one of a threaded chamber cap

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(1482), a plunger (1456), a secondary inert fluid syringe (1457), a secondary pressurizing syringe (1457), and a slidable housing (1461).

5 6. The radioactive gas injection apparatus of claim 1 characterized in that the first and/or the second passageway (1406) comprises a cannula.

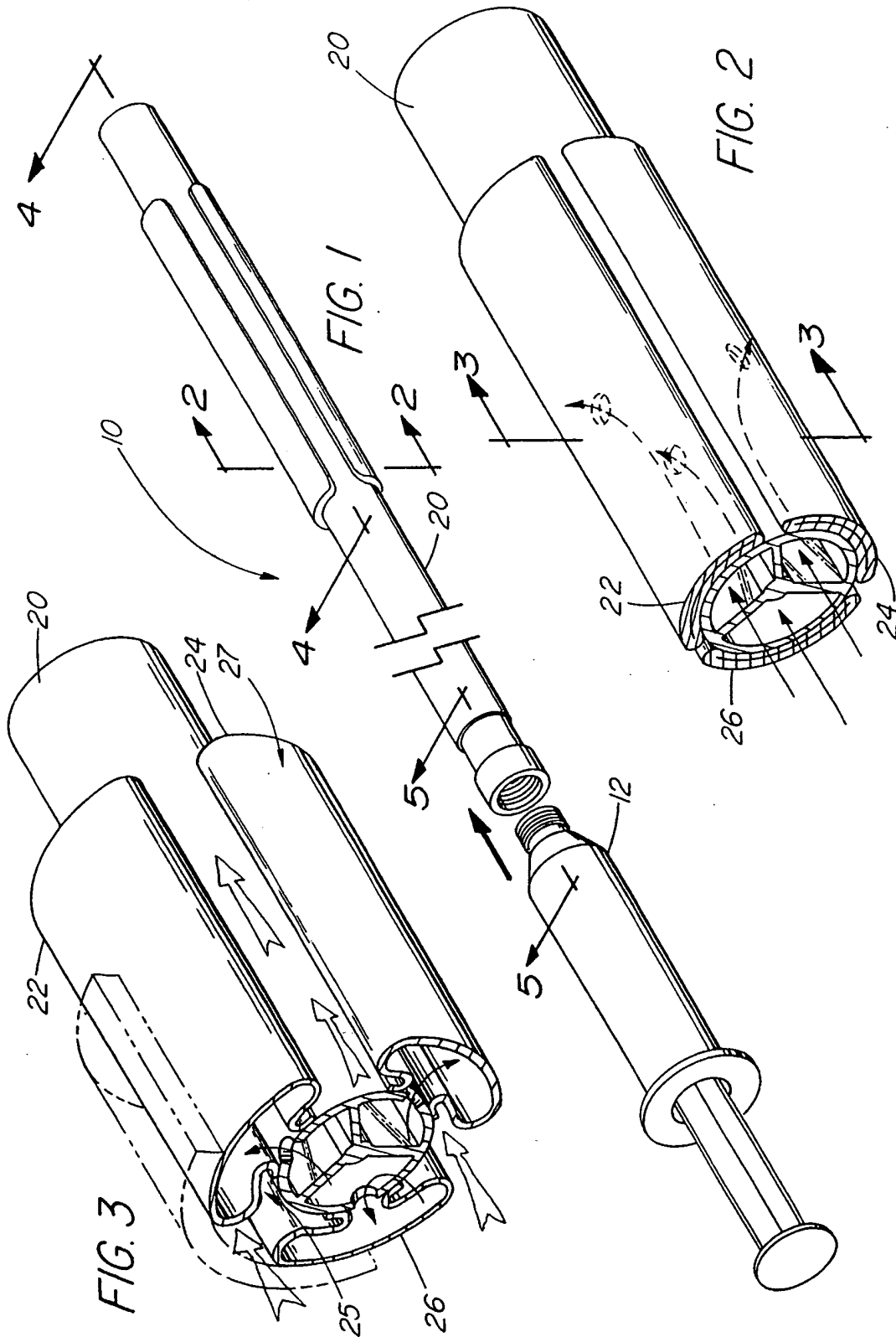
7. The radioactive gas injection apparatus of claim 1 characterized in that the gas-tight variable volume chamber (1411) includes a syringe.

10 8. The radioactive gas injection apparatus of claim 1 characterized in that the selector mechanism (1410) includes a multiple position valve.

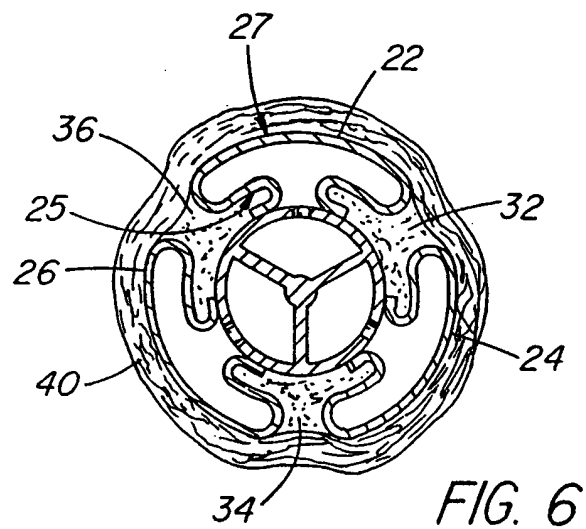
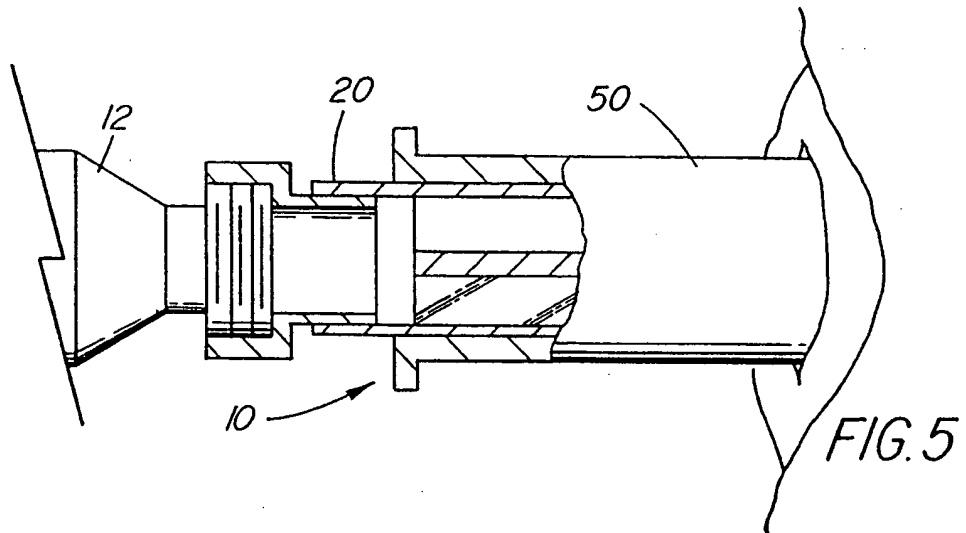
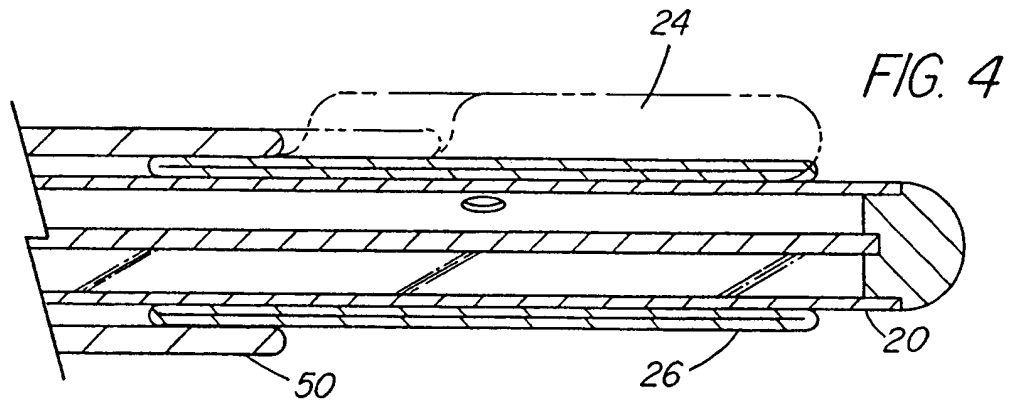
15 9. The radioactive gas injection apparatus of claim 1 characterized in that the apparatus (1400) further includes a pressure gauge (1414) connected to the second passageway (1454).

10. The radioactive gas injection apparatus of claim 1 characterized in that the apparatus (1400) further includes at least one vacuum line (1423, 1425).

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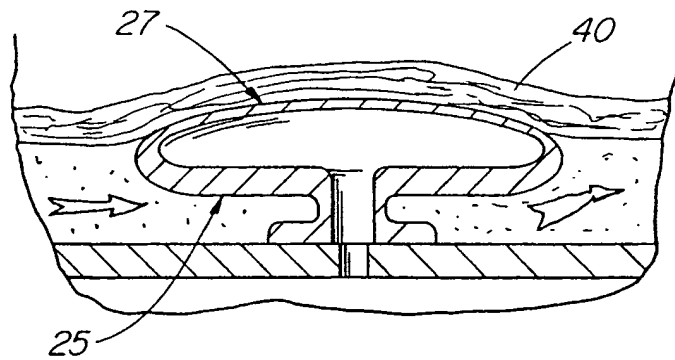


FIG. 7

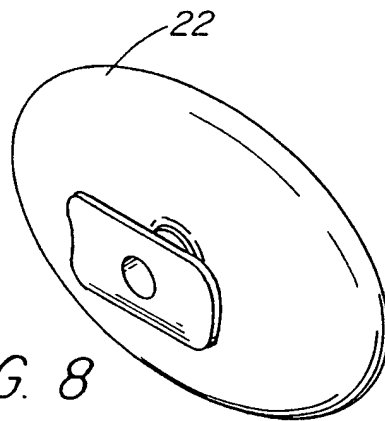


FIG. 8

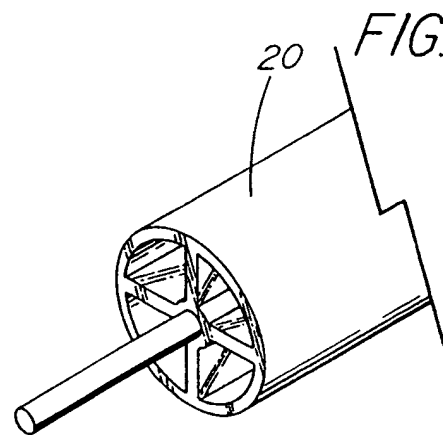


FIG. 9

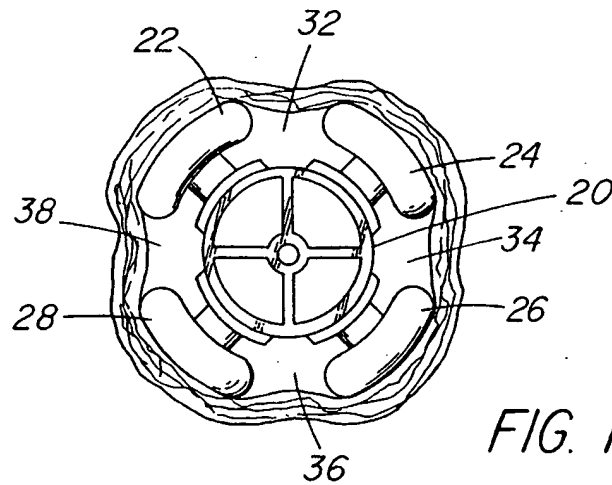
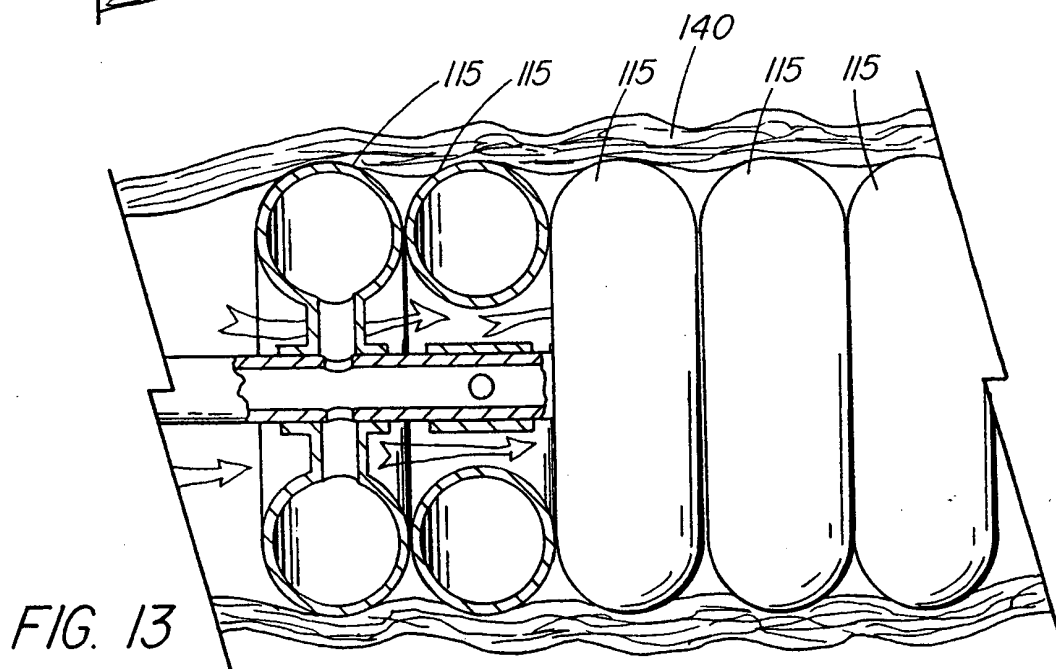
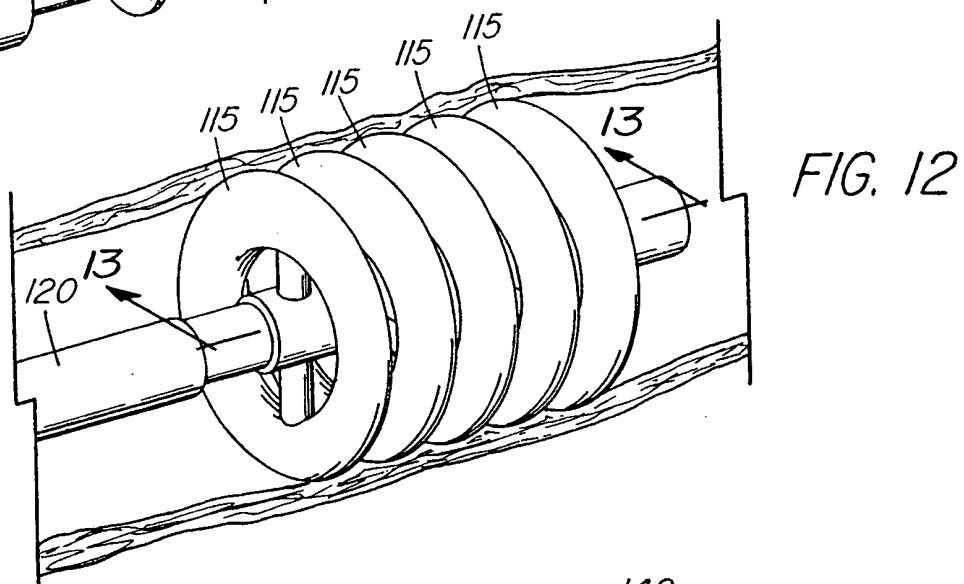
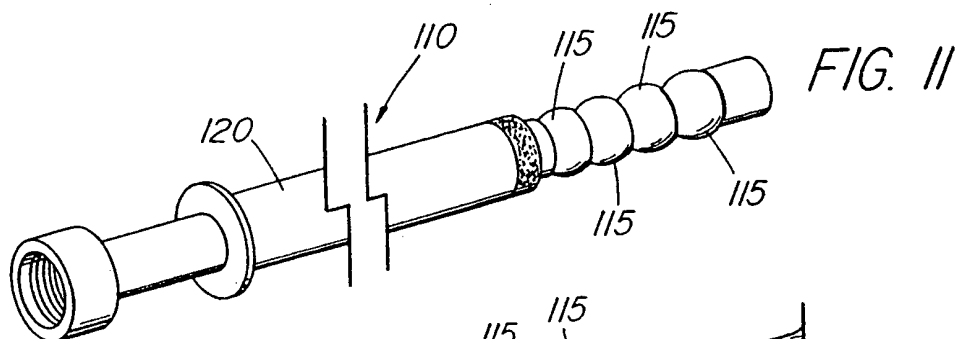


FIG. 10

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FIG. 14

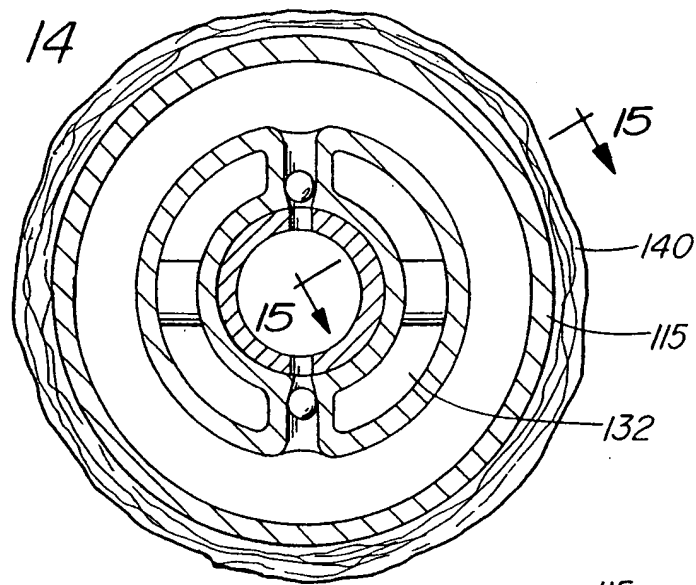


FIG. 15

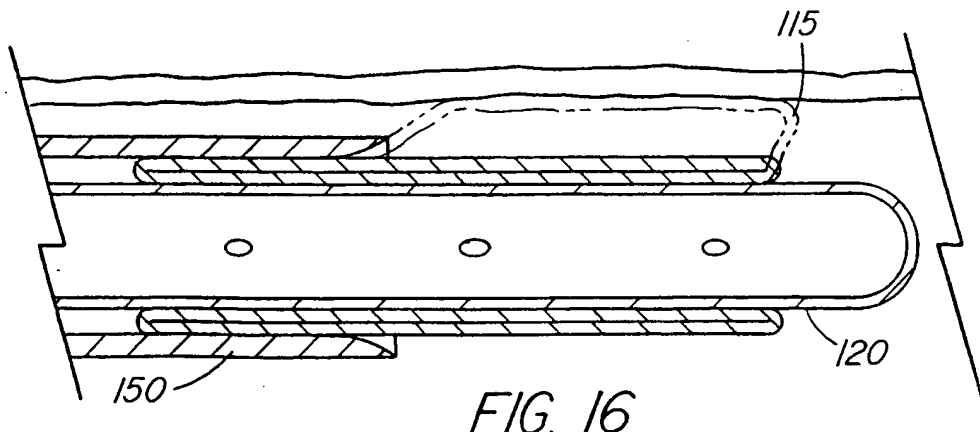
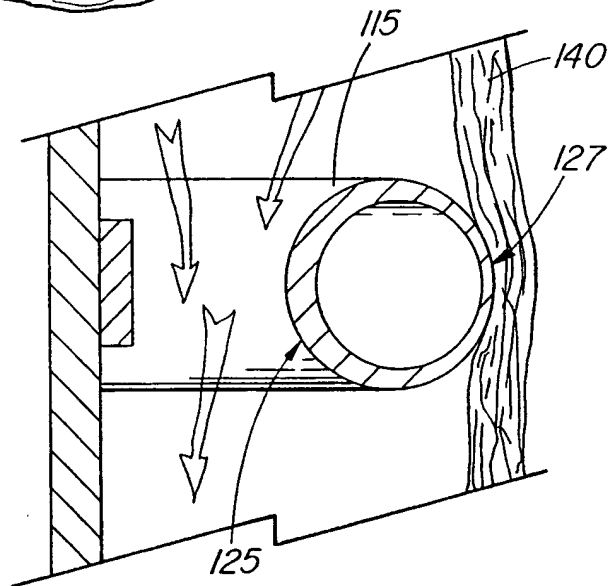
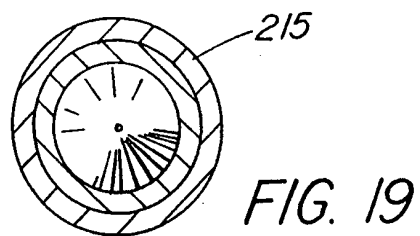
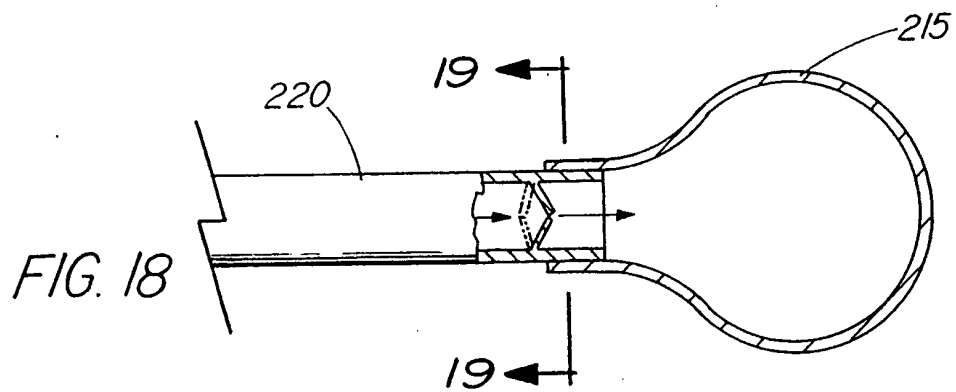
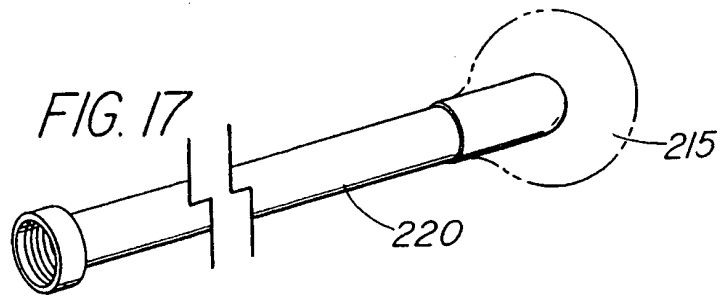


FIG. 16

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FIG. 20

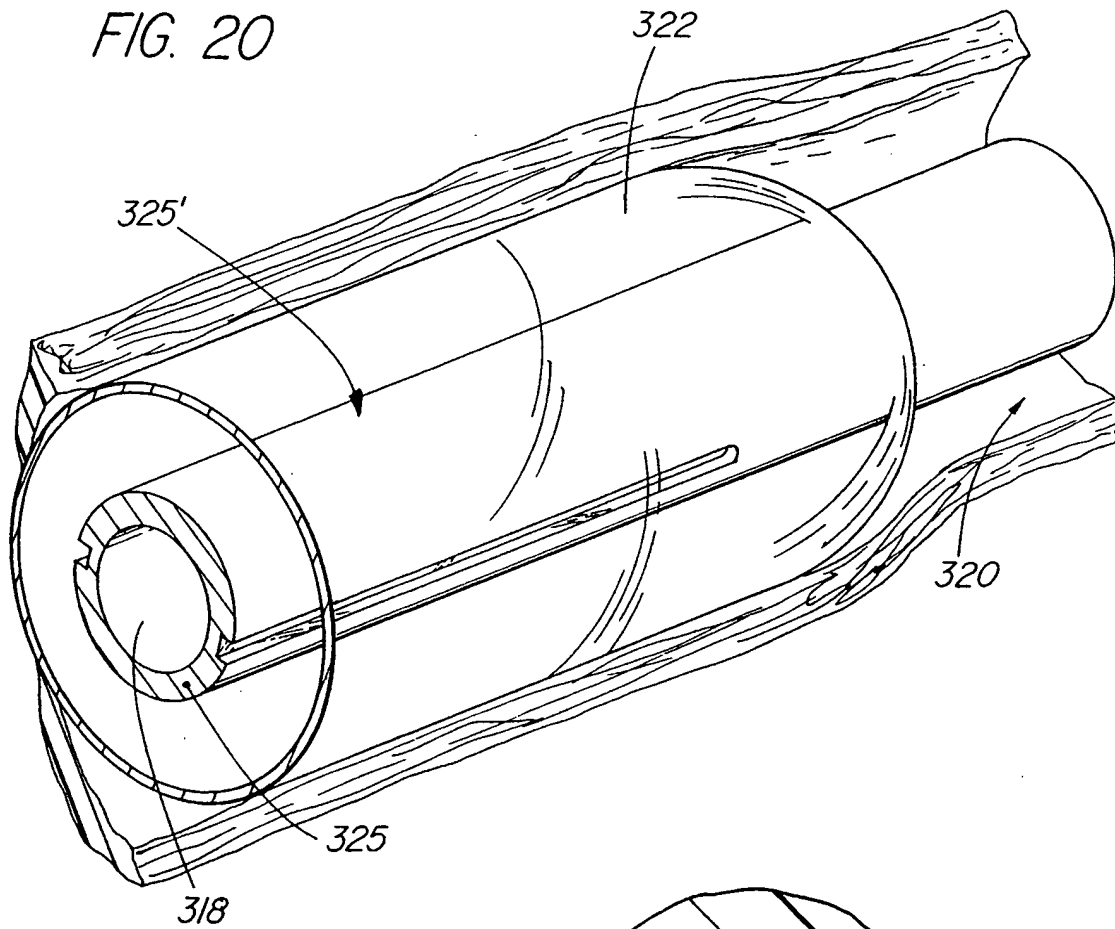
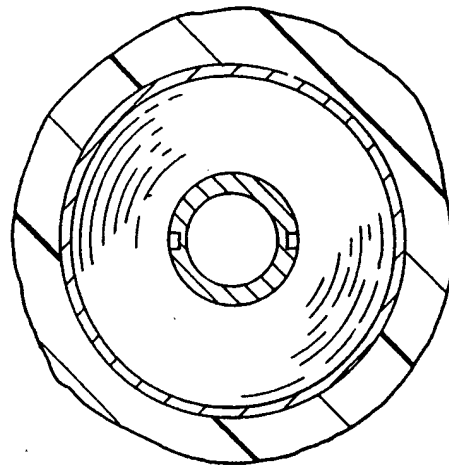


FIG. 21



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FIG. 22

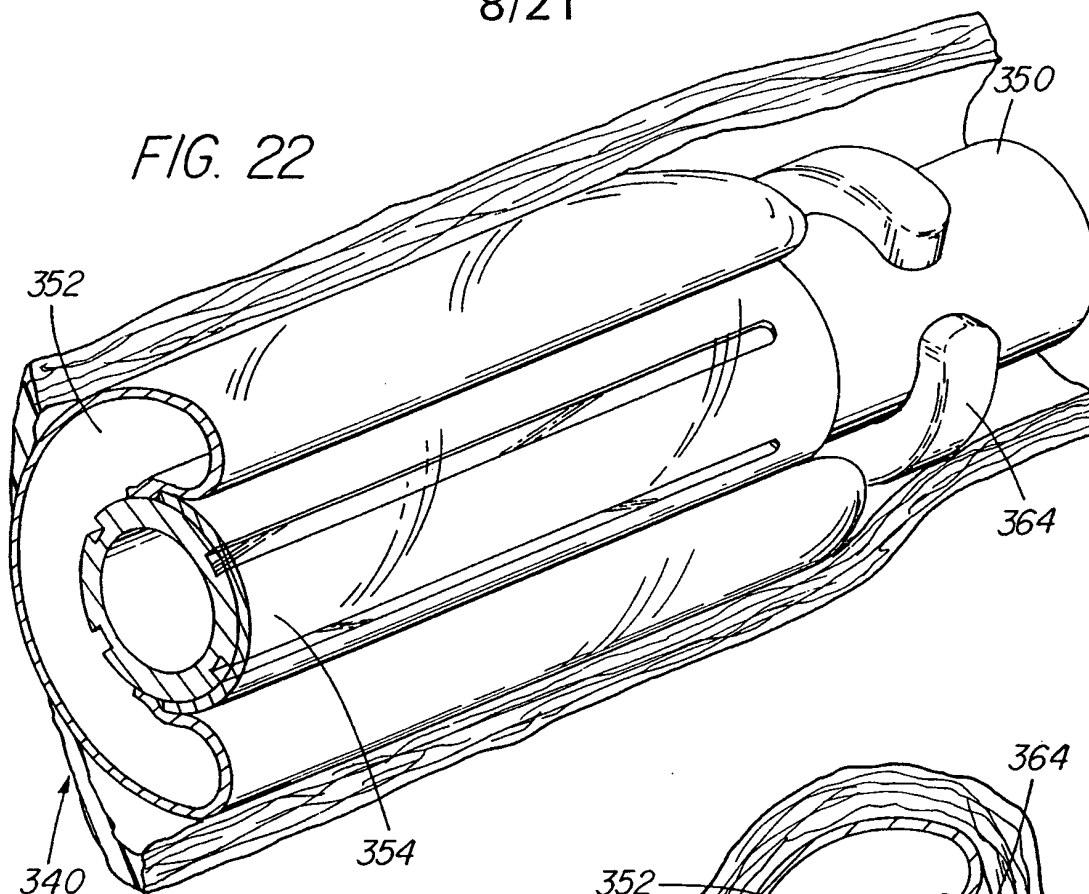


FIG. 23

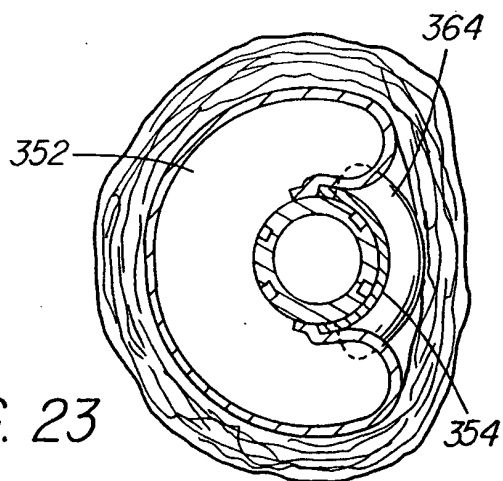
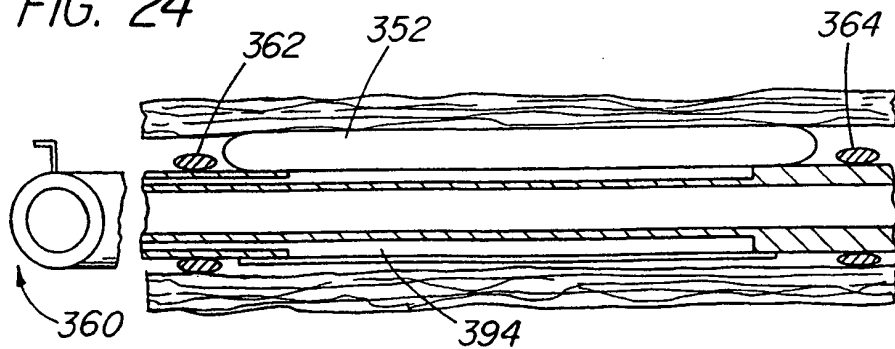
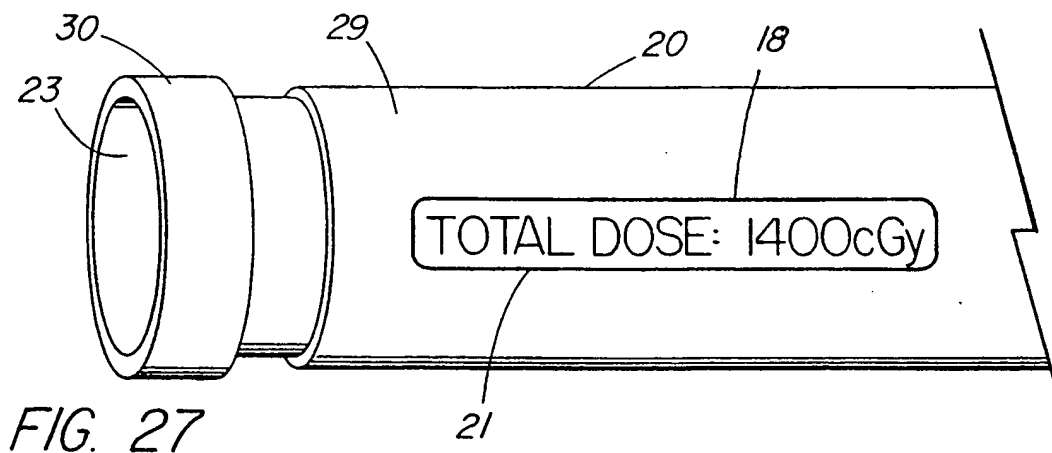
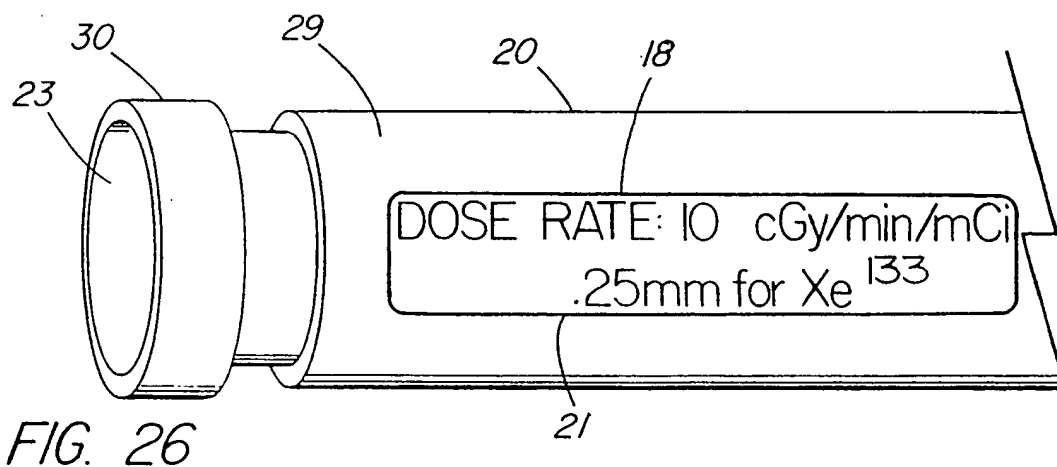
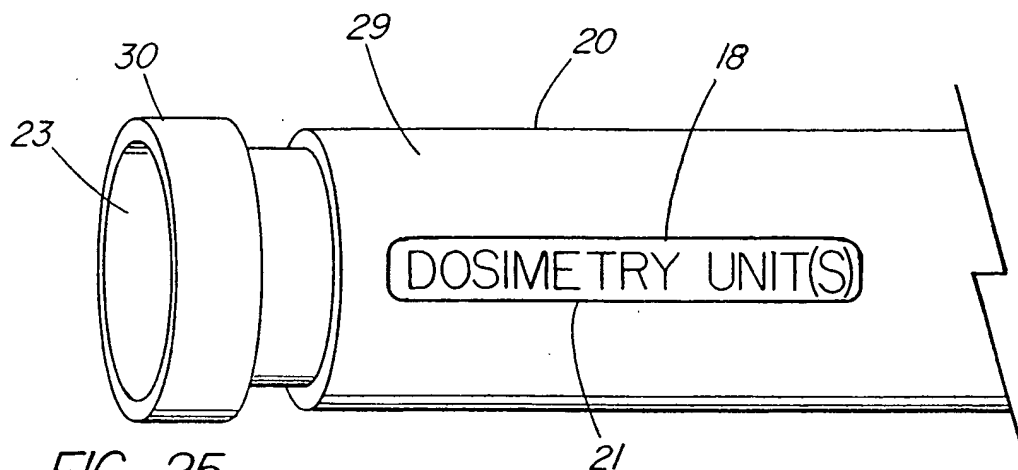


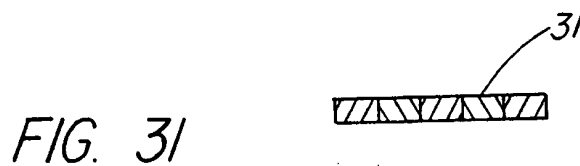
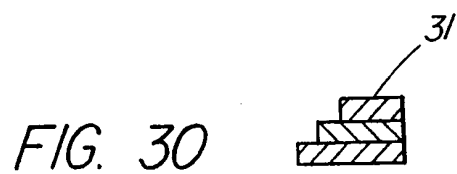
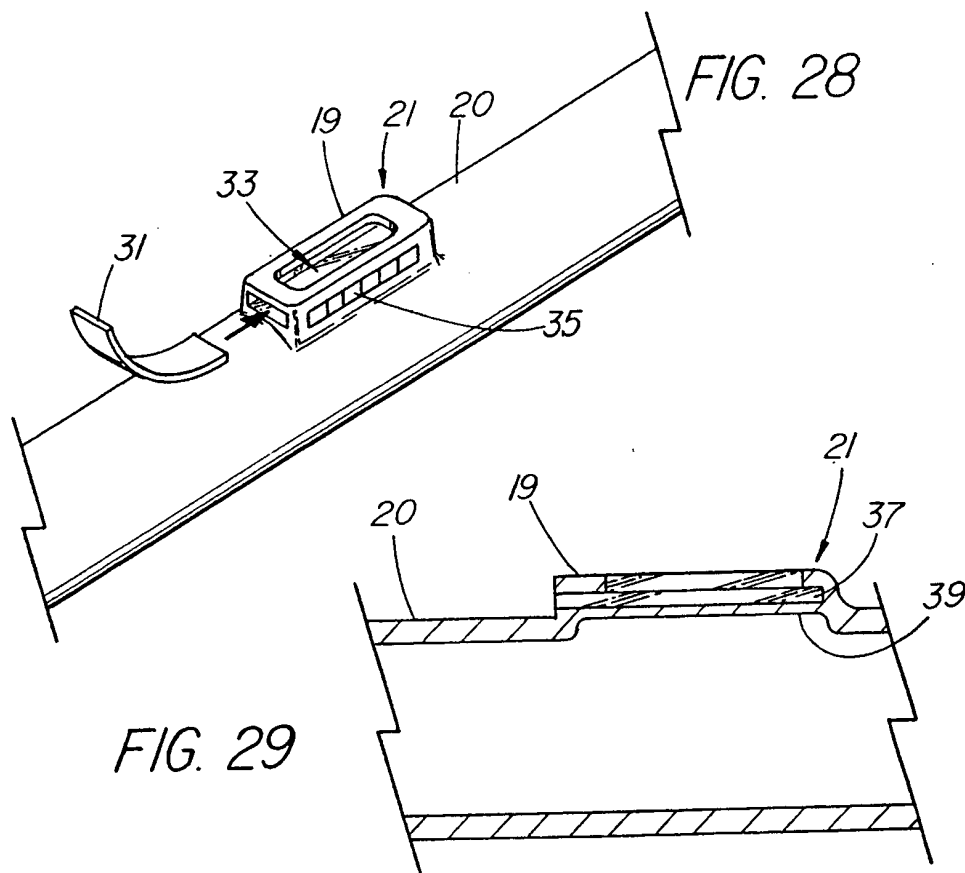
FIG. 24



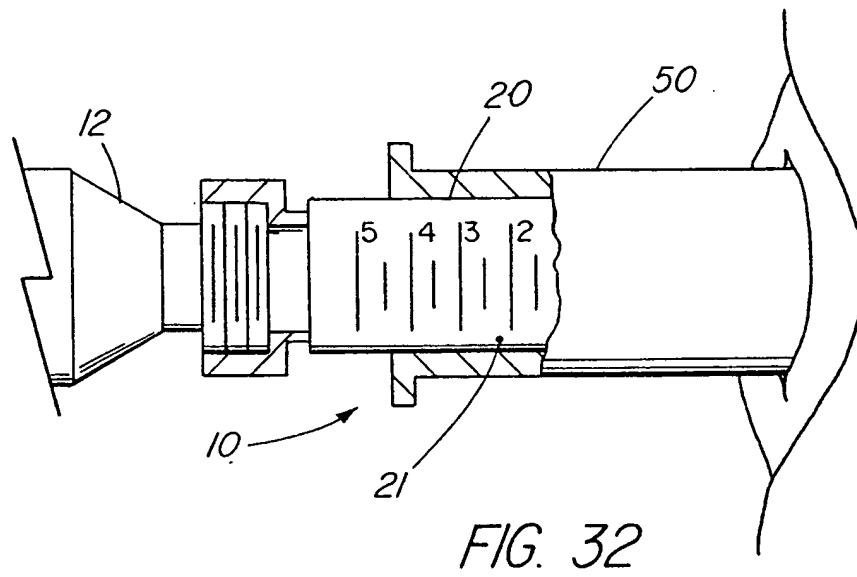
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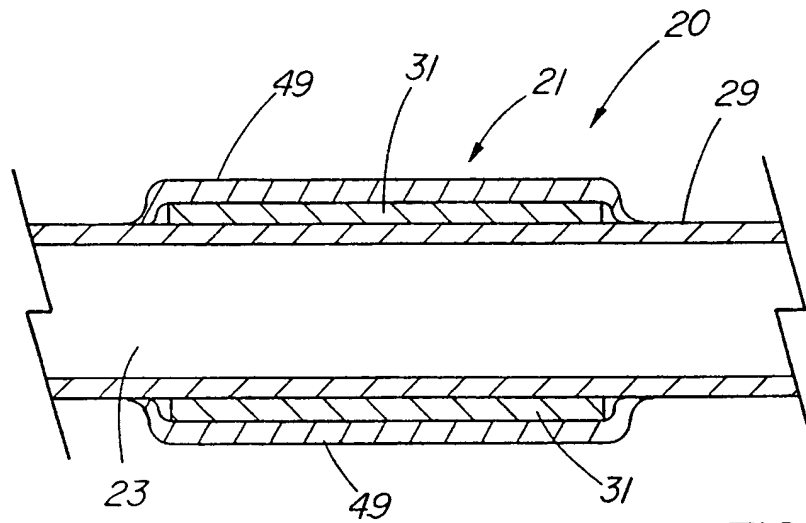


FIG. 33

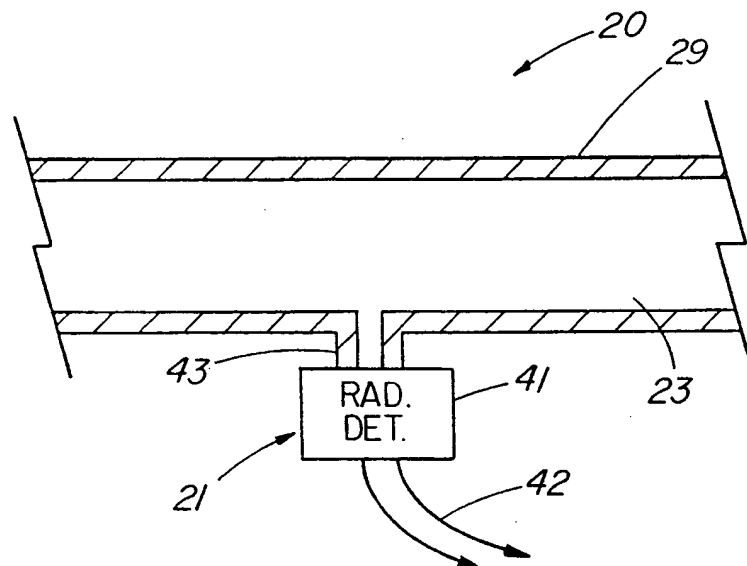
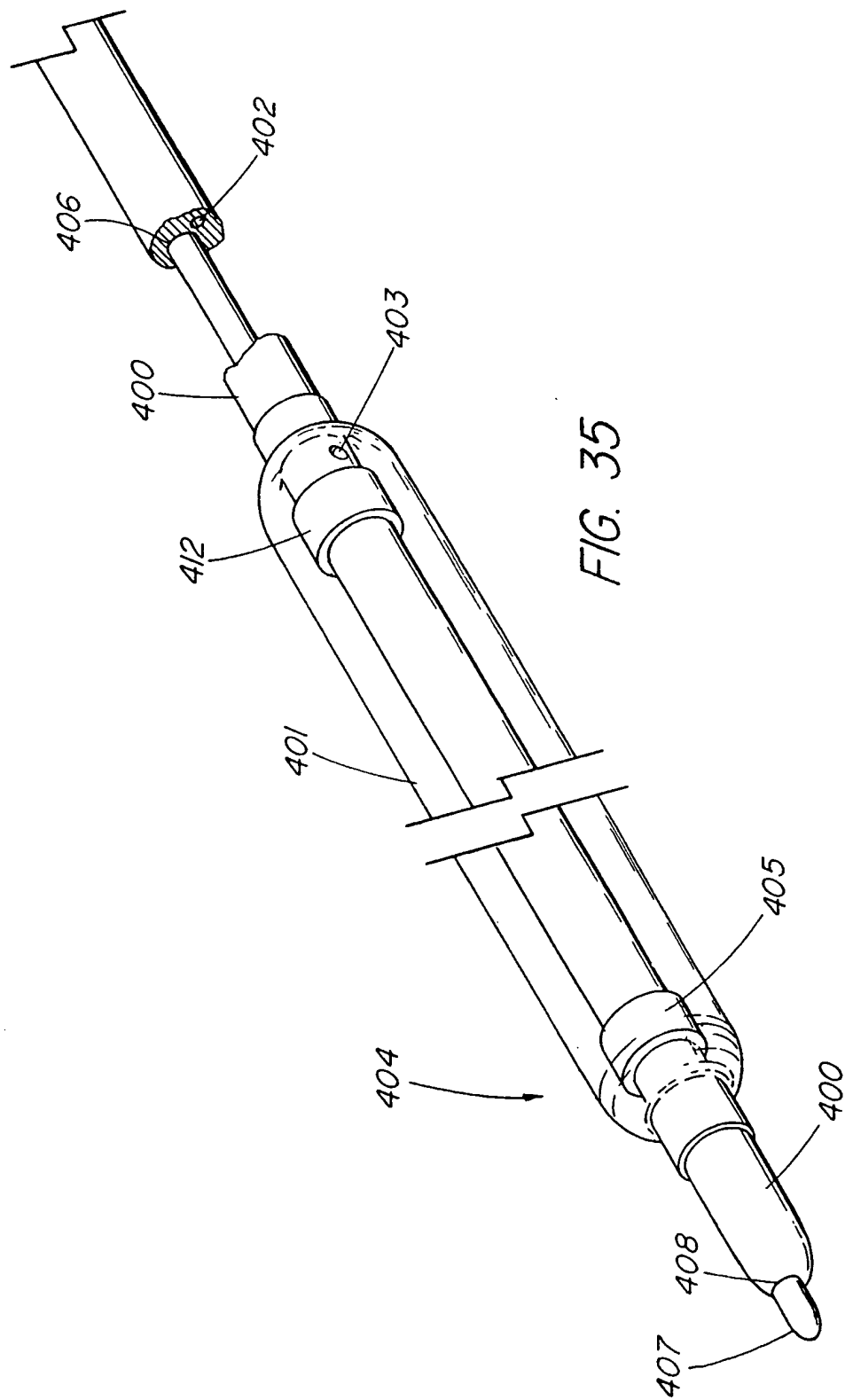


FIG. 34

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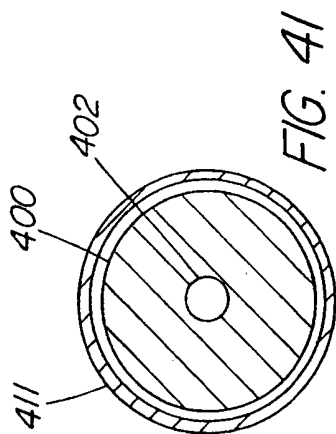


FIG. 41

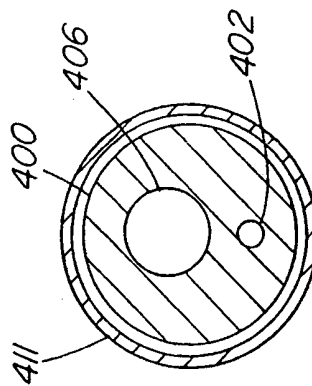


FIG. 38

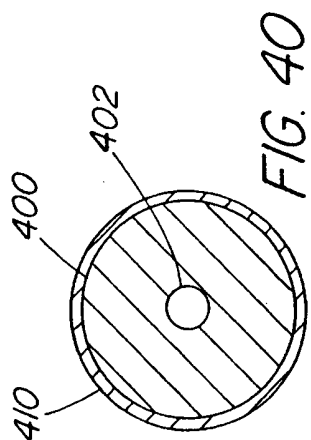


FIG. 40

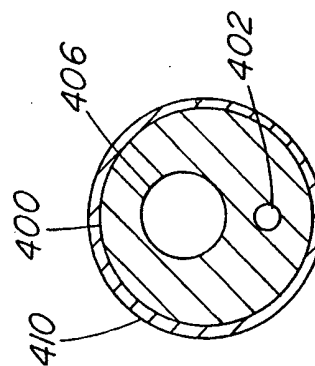


FIG. 37

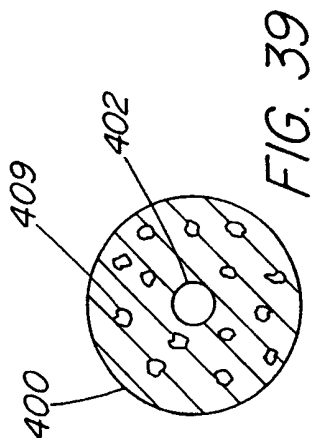


FIG. 39

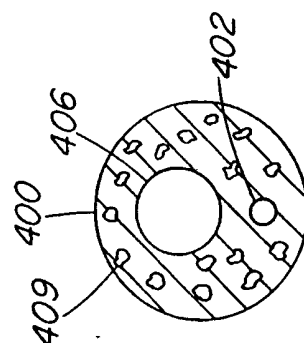


FIG. 36

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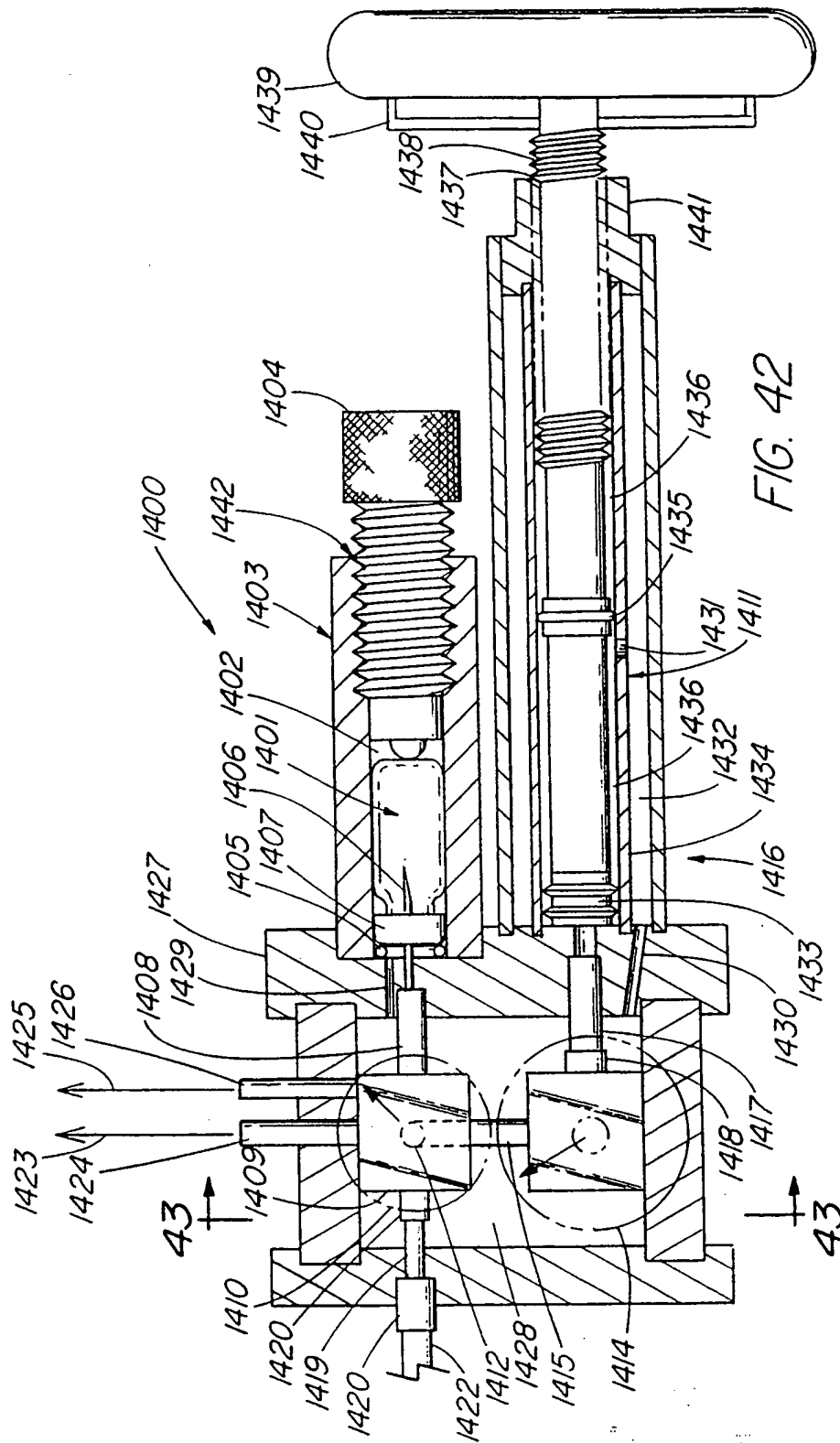
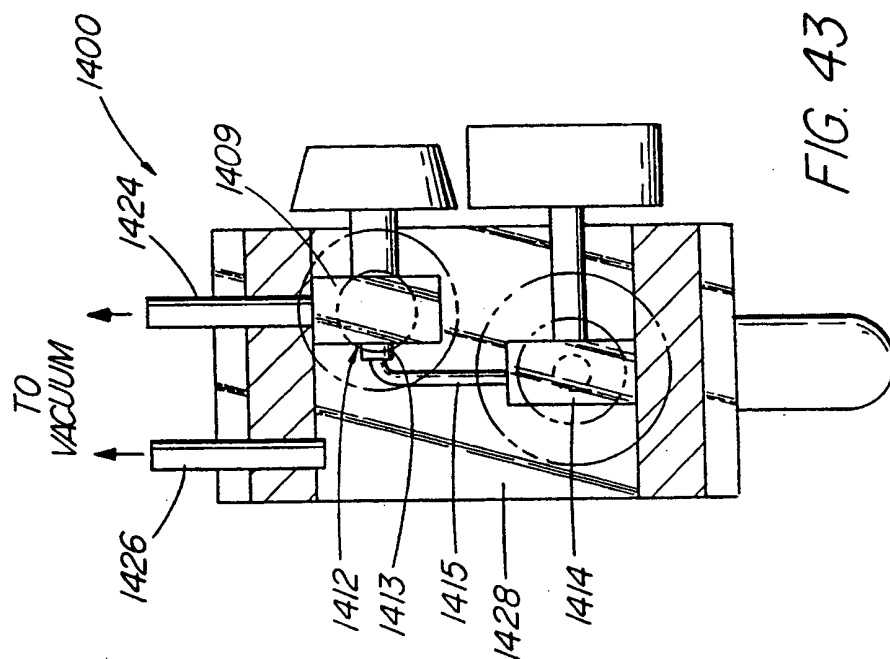


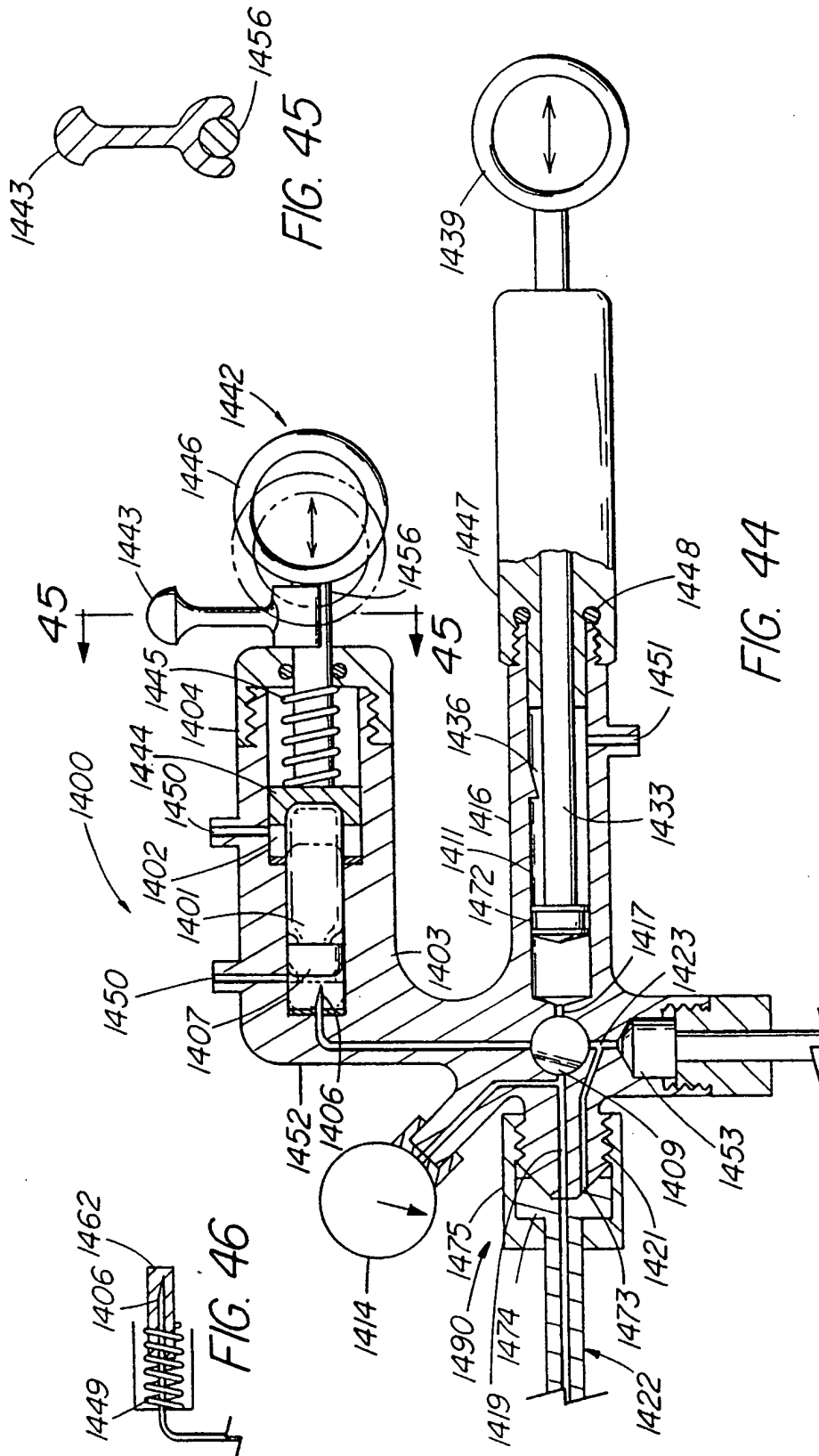
FIG. 42

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SUBSTITUTE SHEET (RULE 26)

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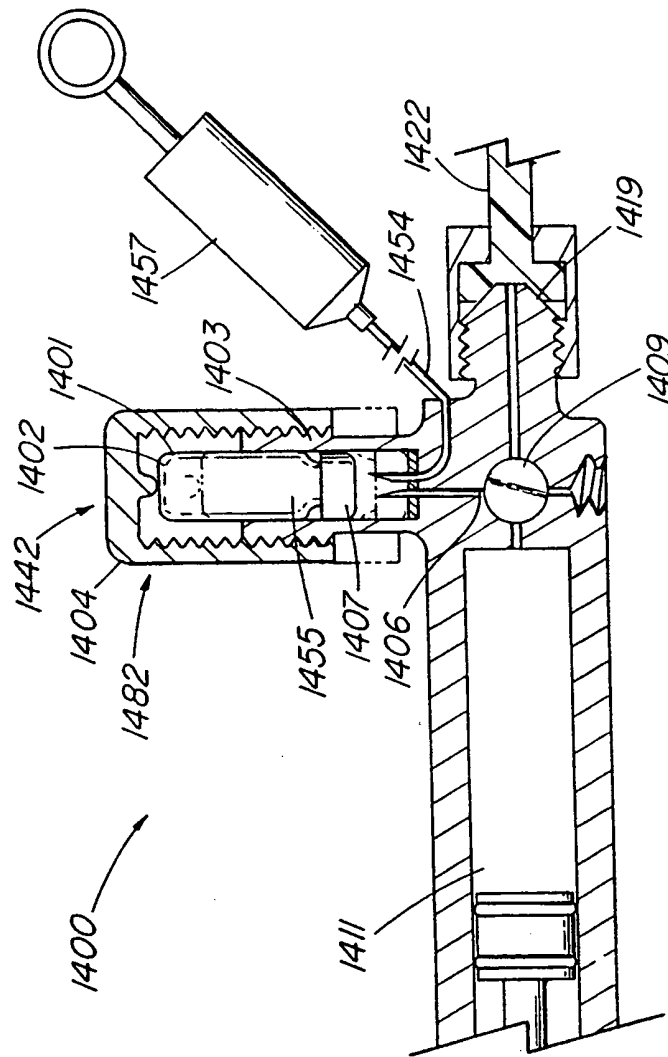
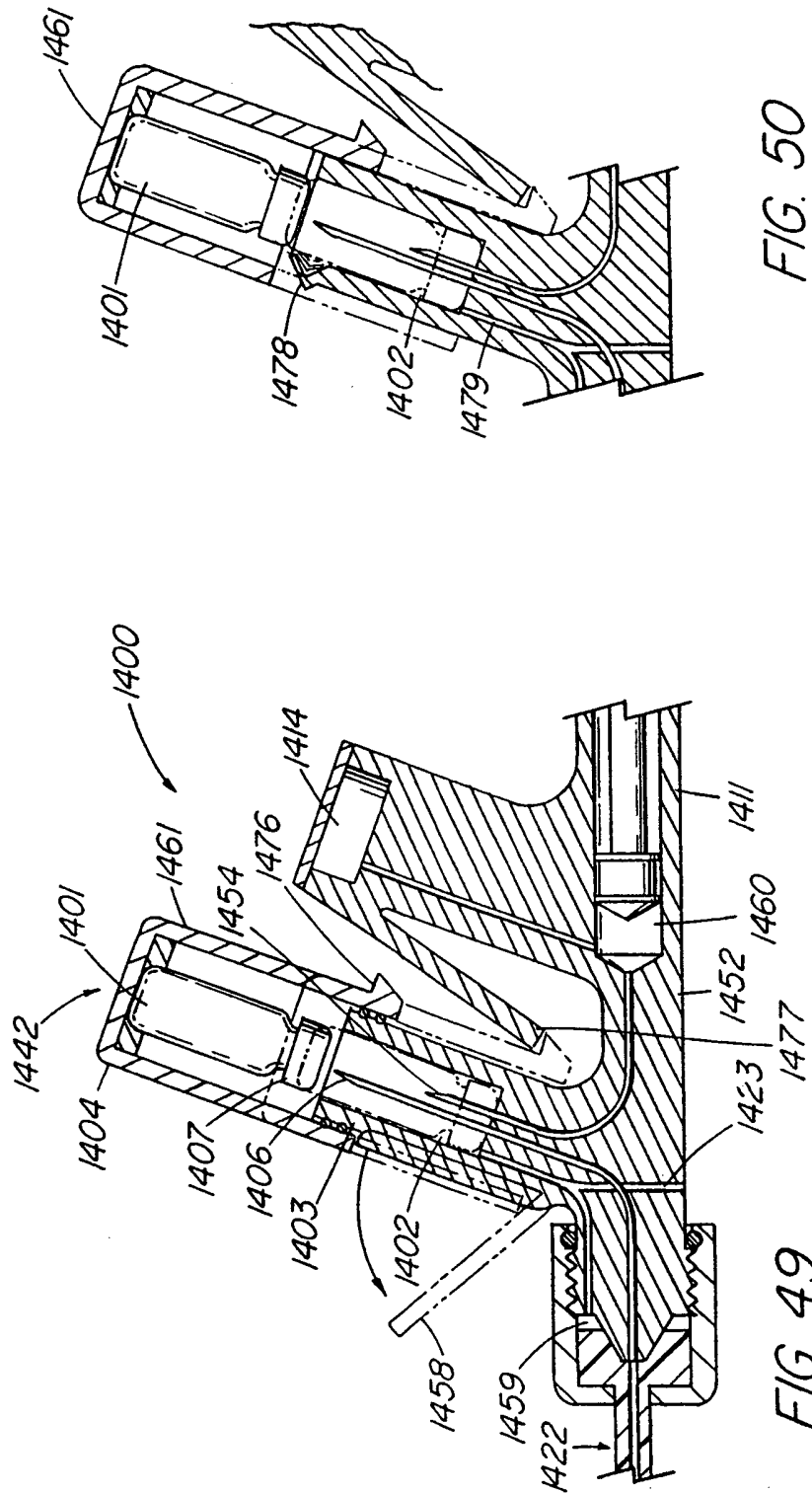


FIG. 47

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SUBSTITUTE SHEET (RULE 26)

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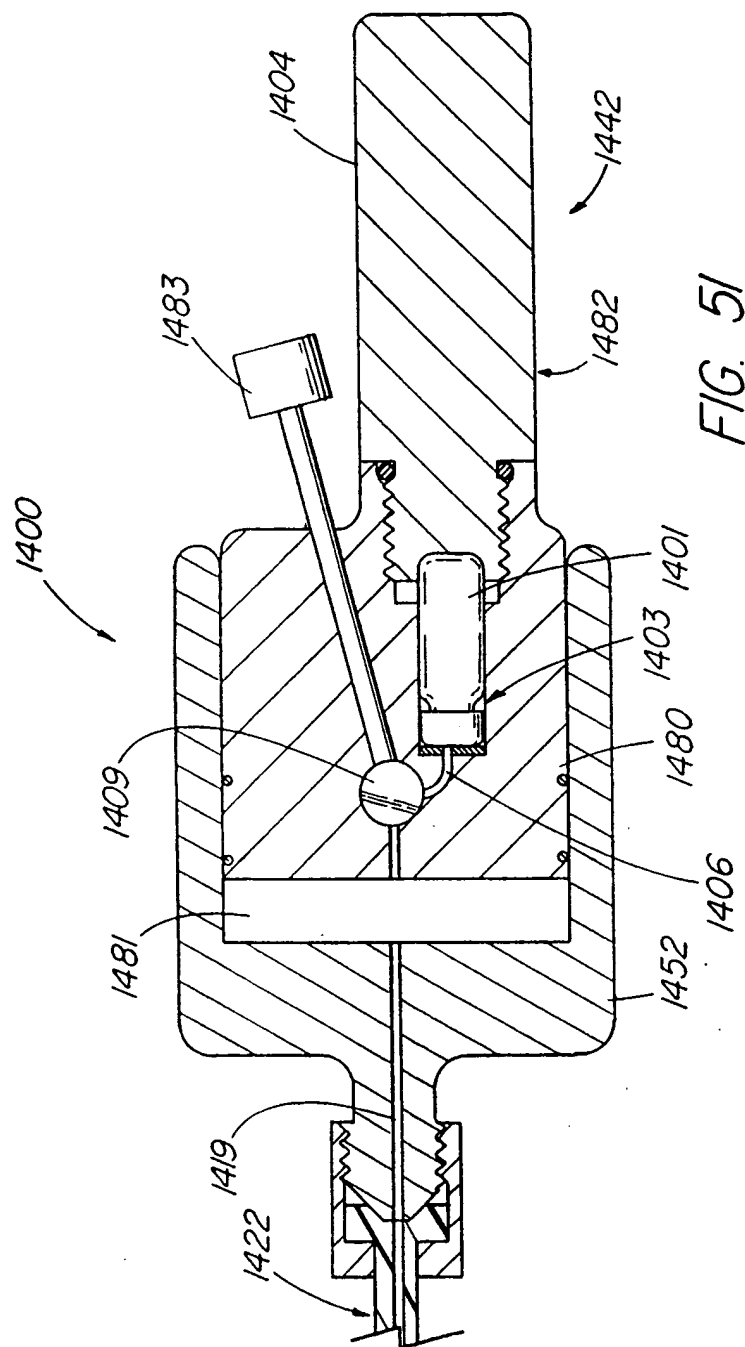
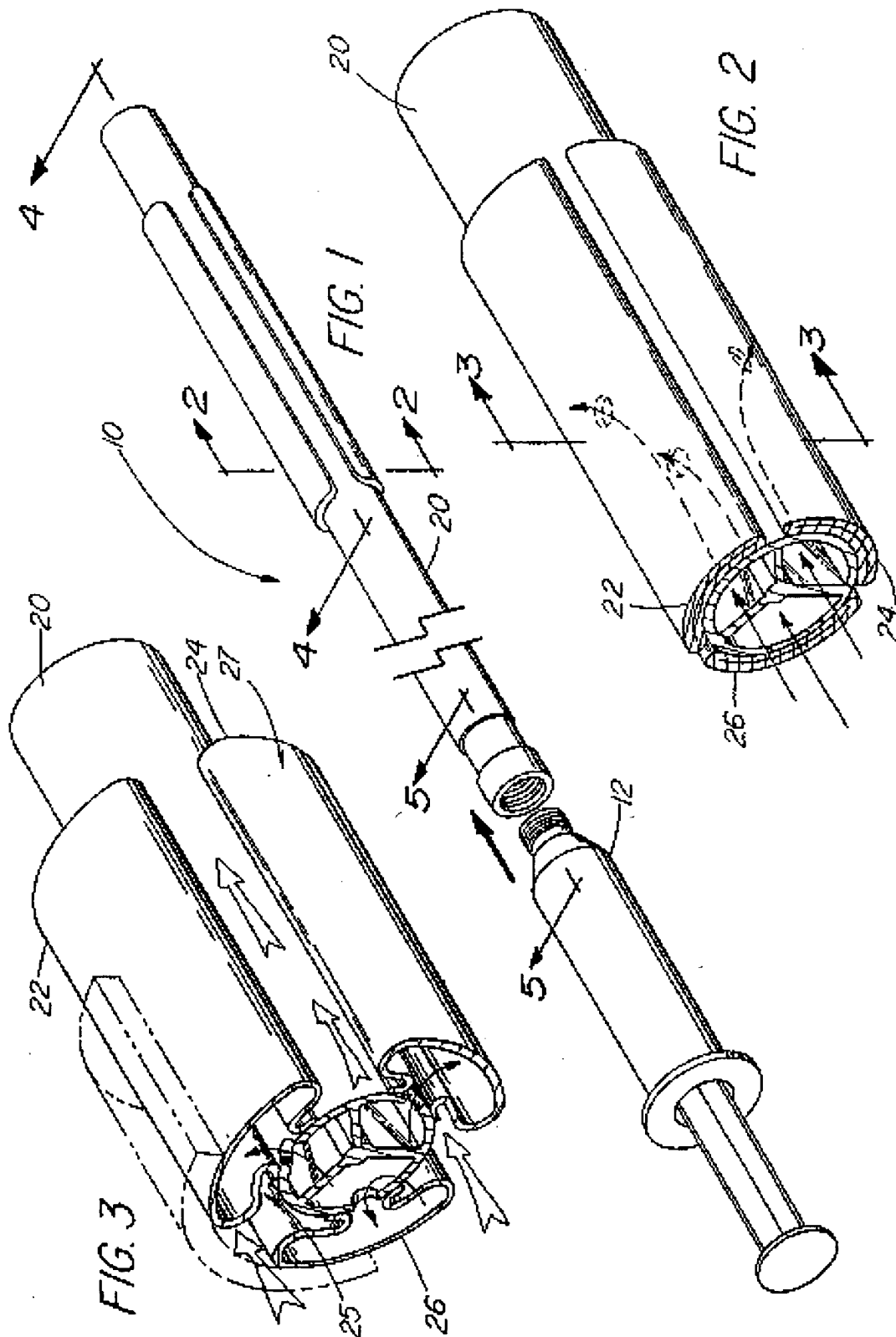
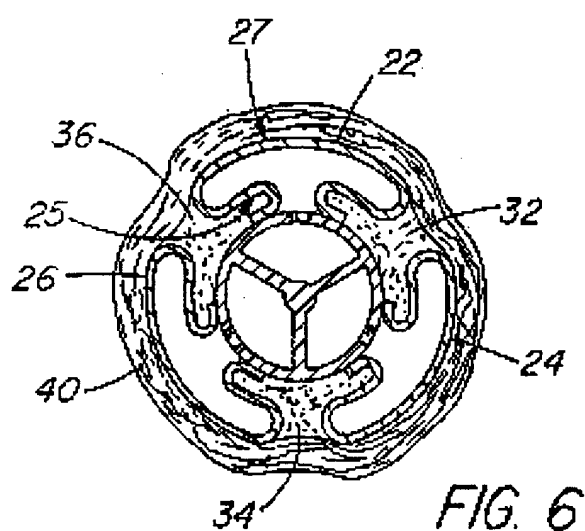
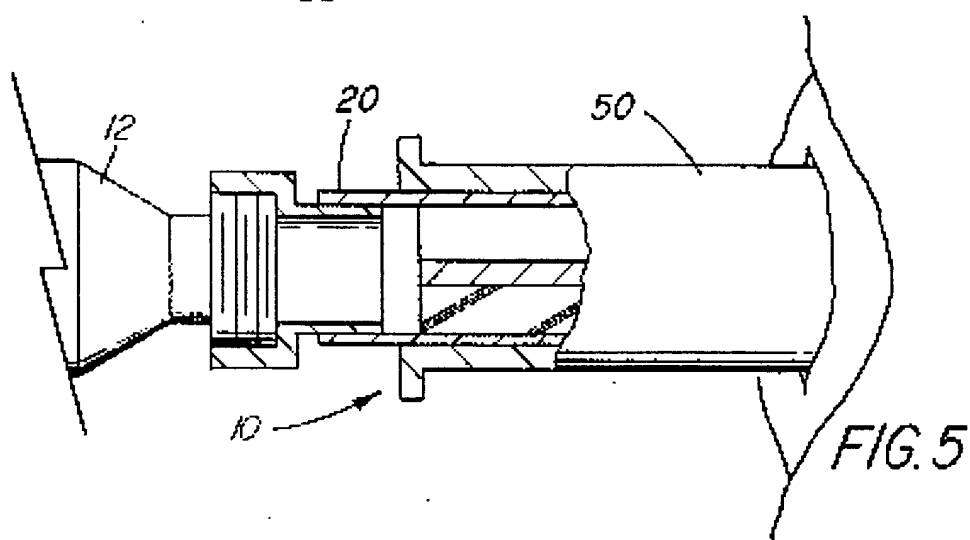
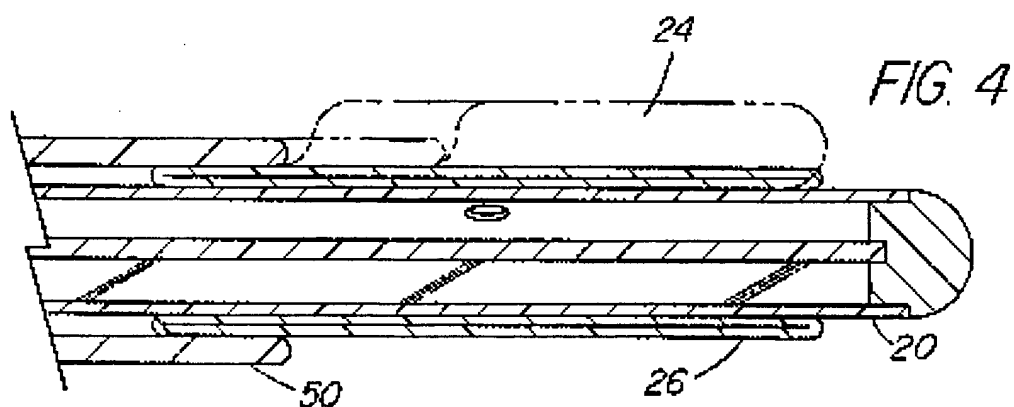


FIG. 5I

1. The first part of the document is a list of the names of the persons who have been appointed to the various positions of the Board of Directors of the Corporation. The names are as follows:



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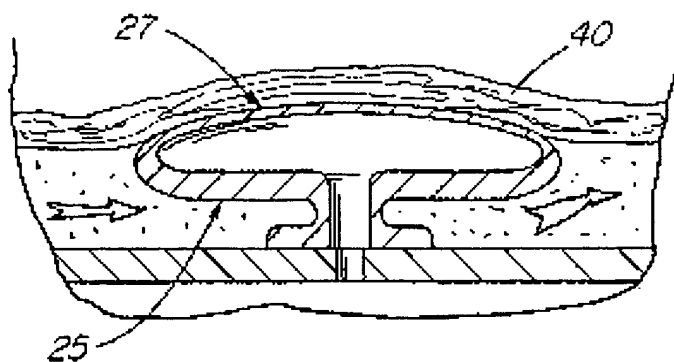


FIG. 7

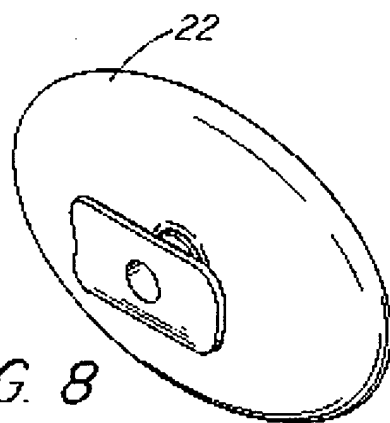


FIG. 8

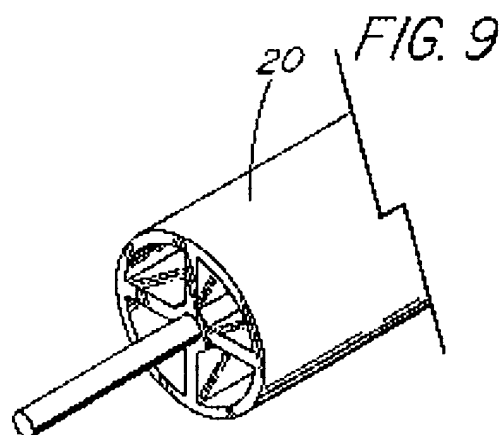


FIG. 9

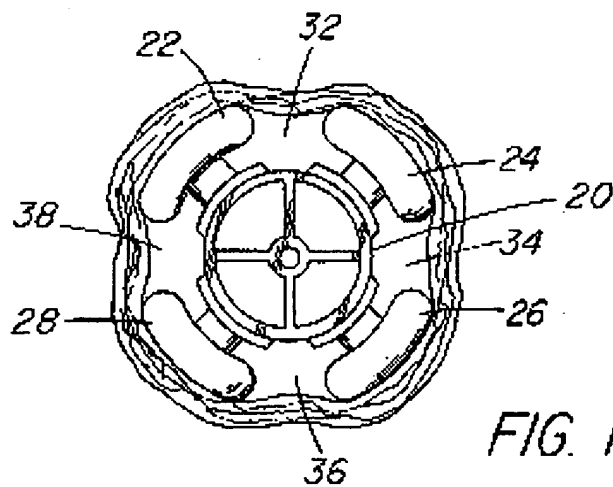
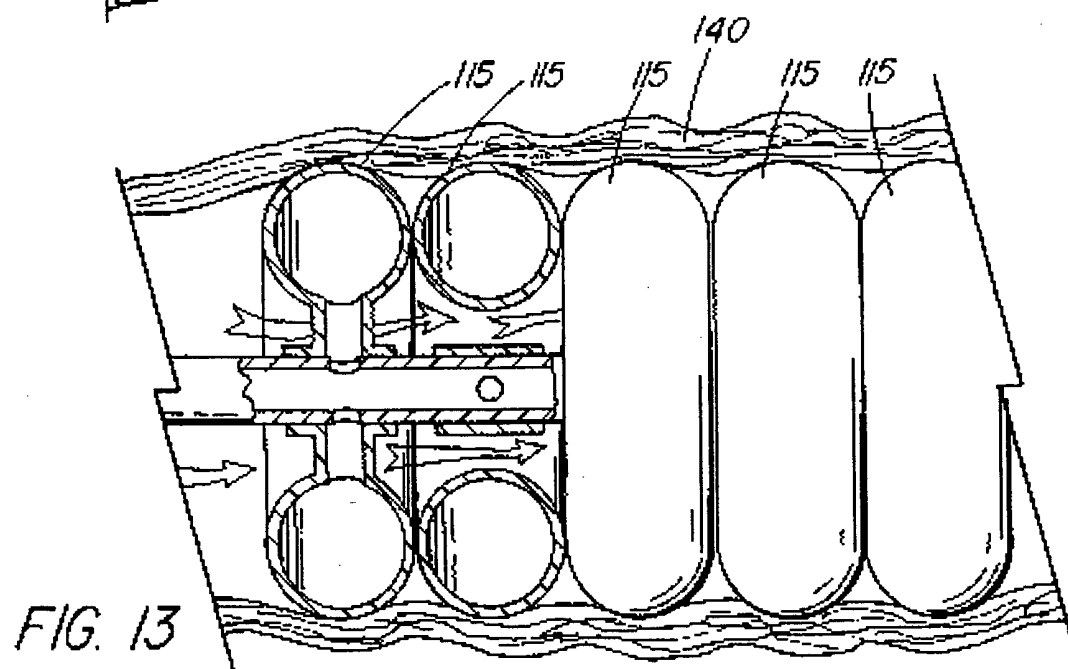
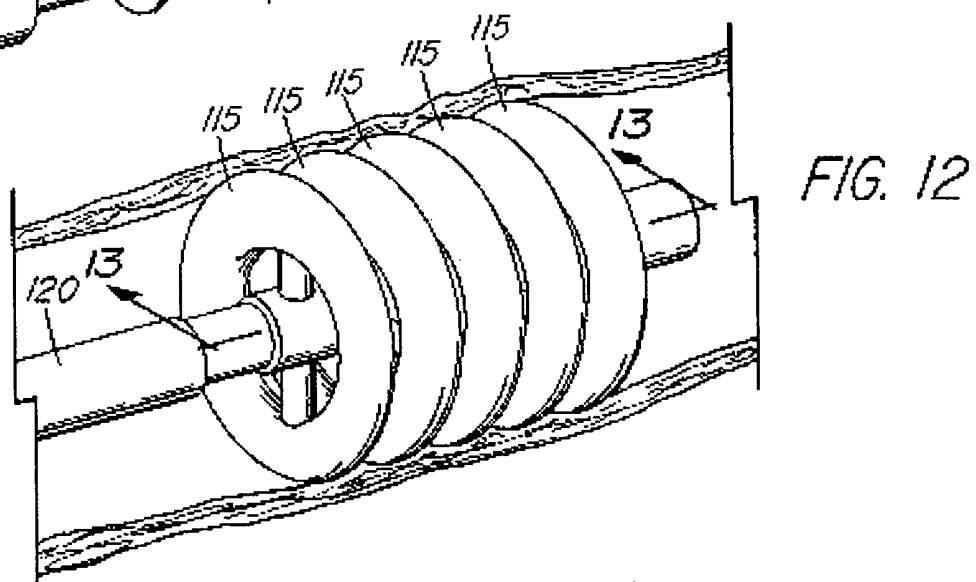
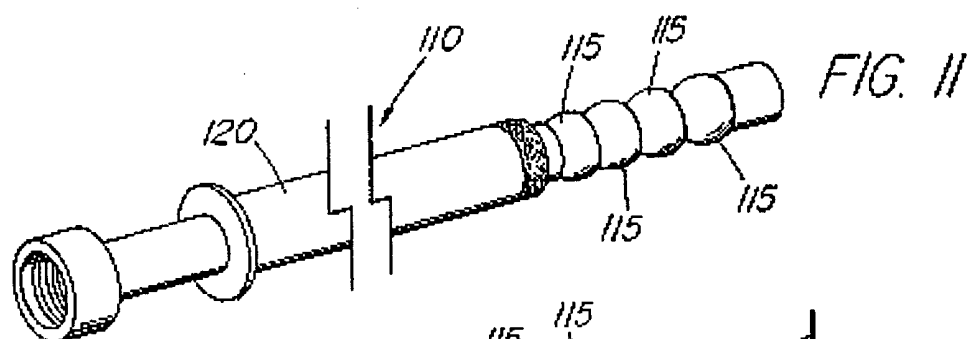


FIG. 10

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FIG. 14

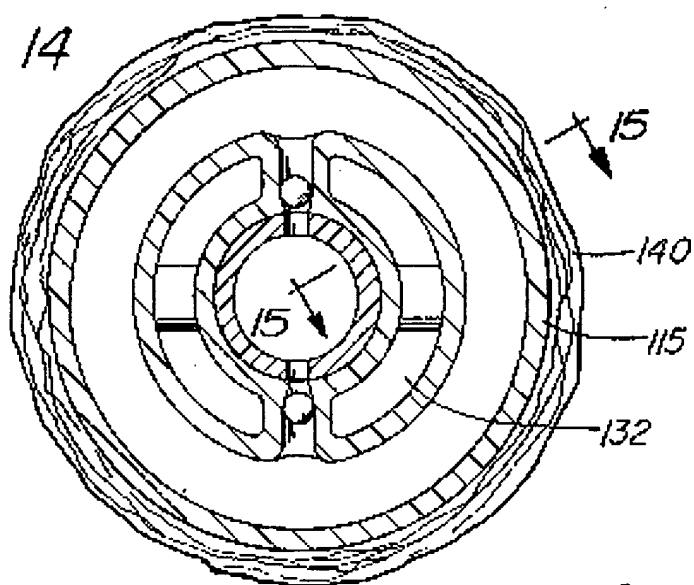


FIG. 15

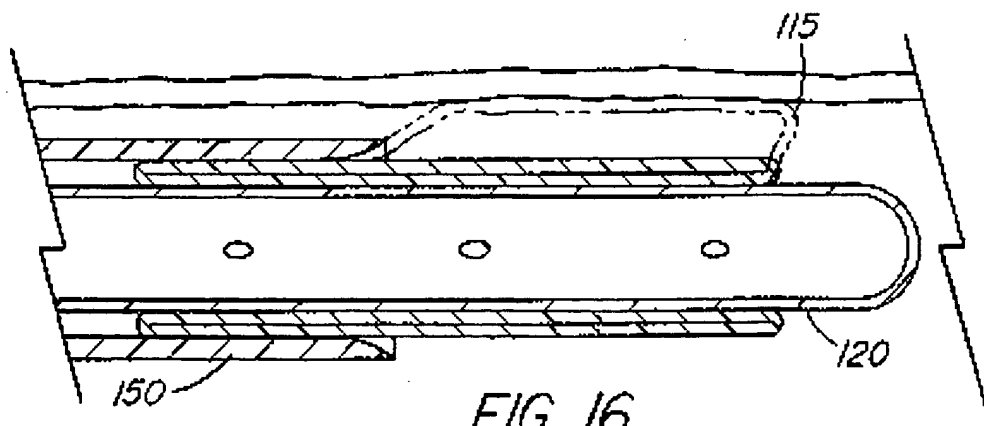
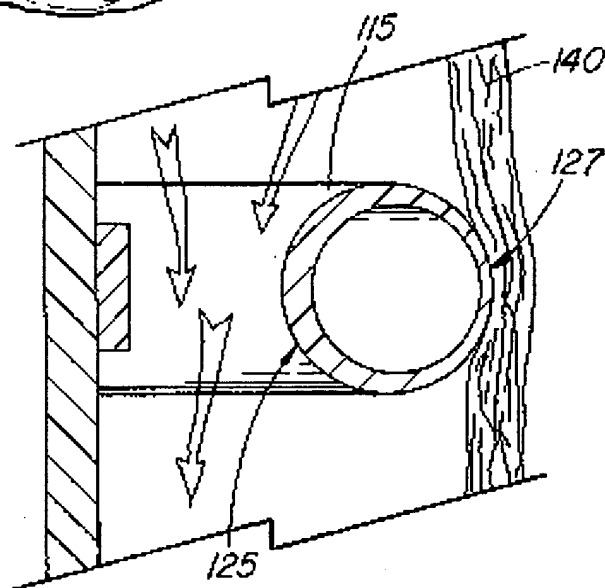
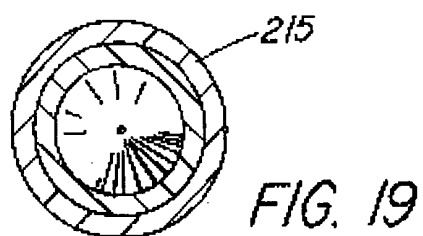
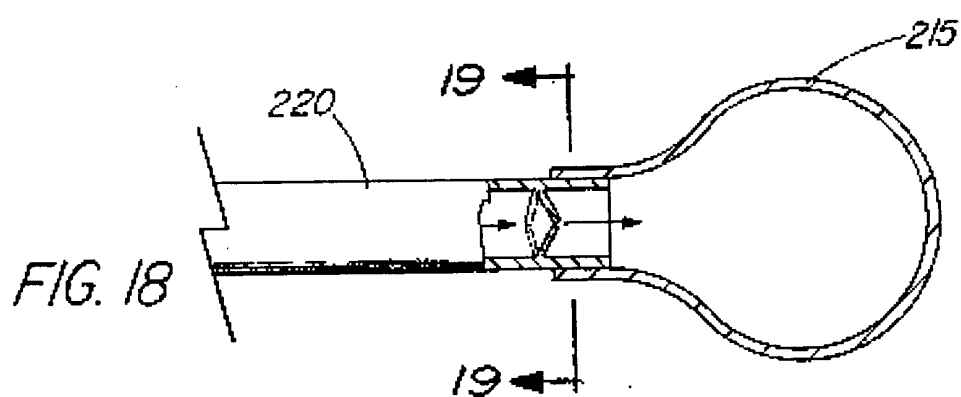
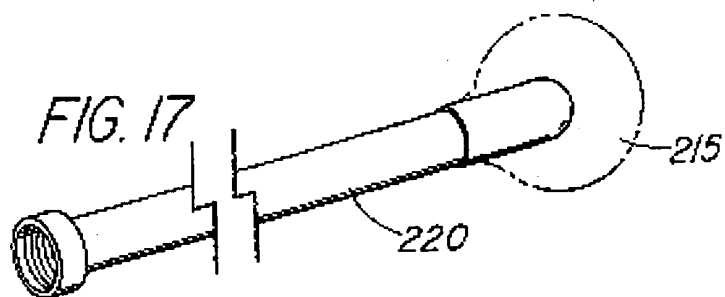


FIG. 16

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FIG. 20

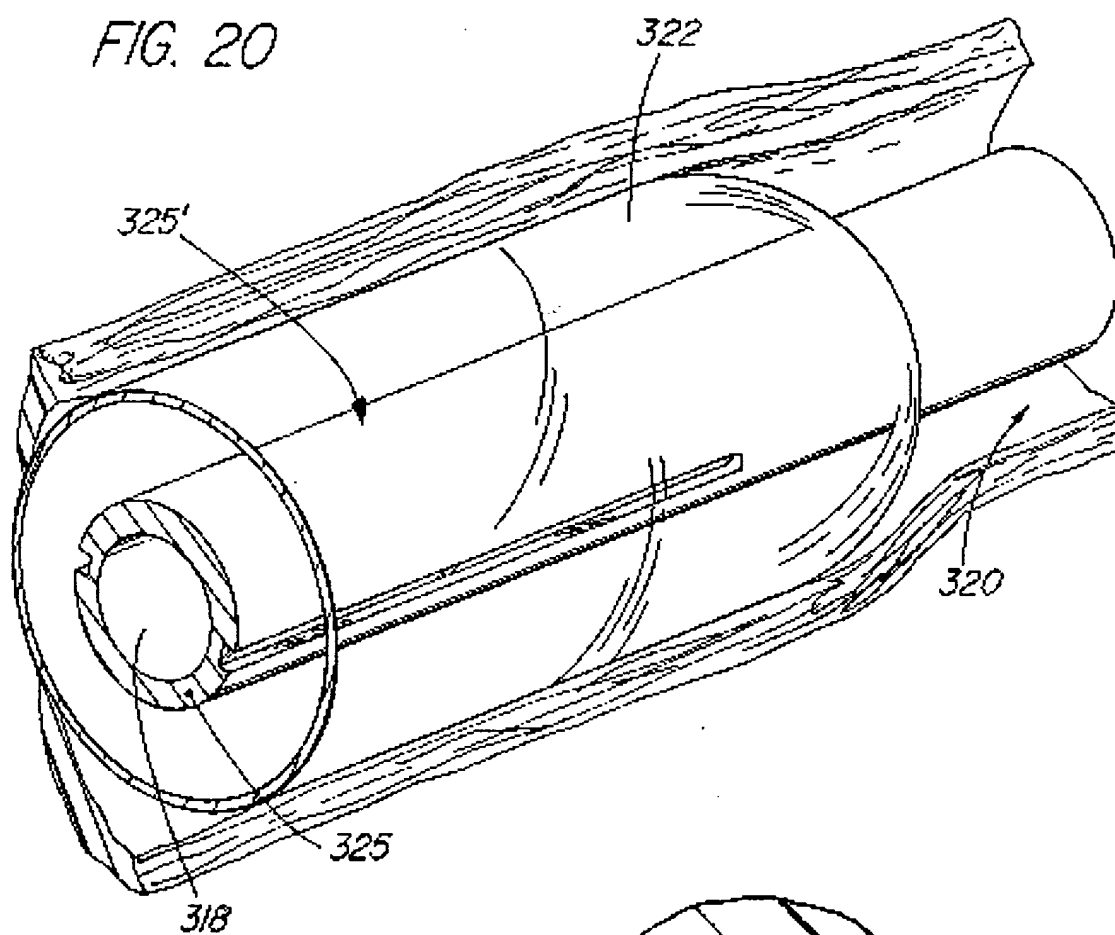
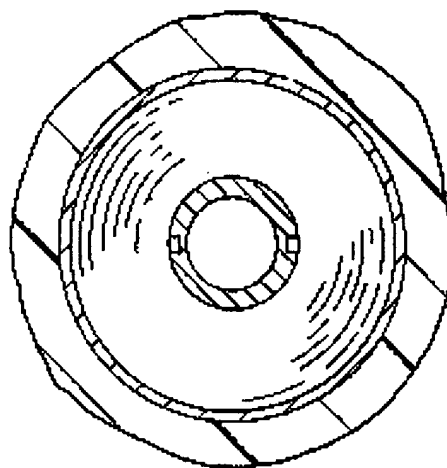


FIG. 21



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FIG. 22

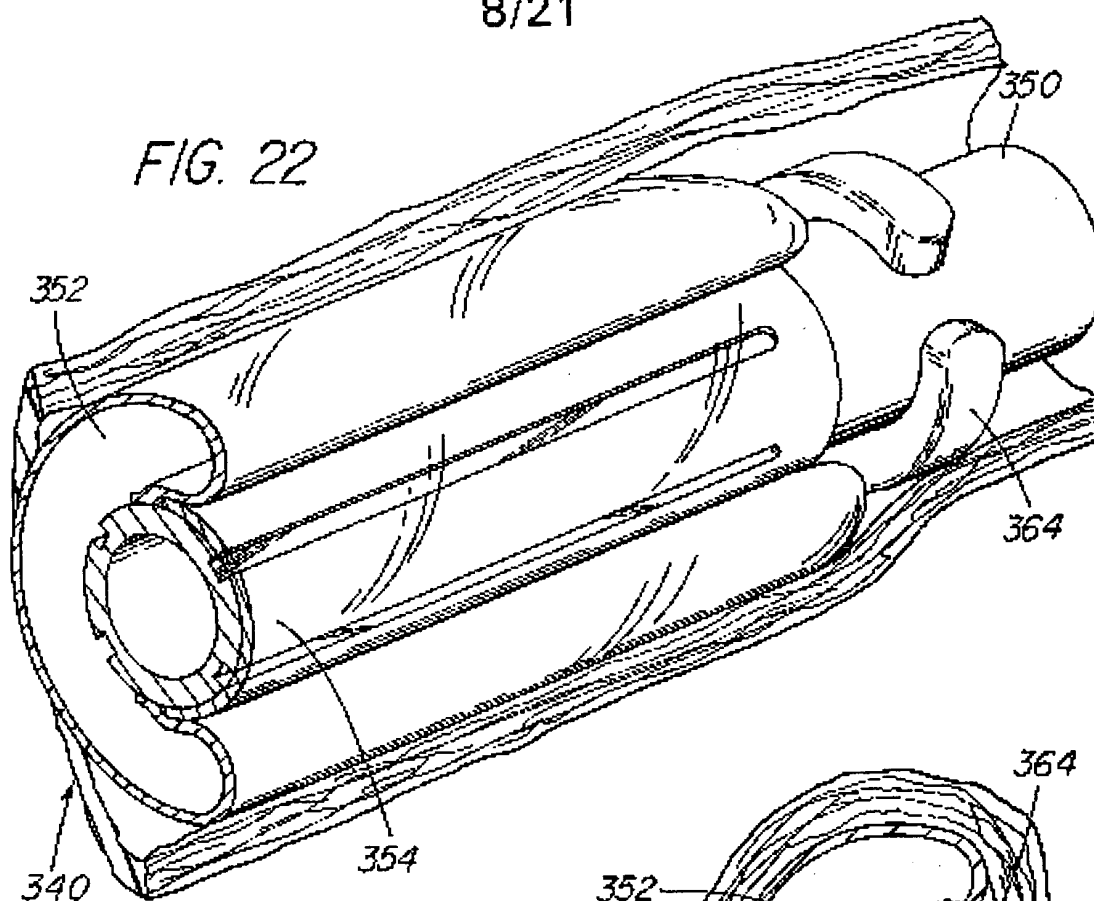


FIG. 23

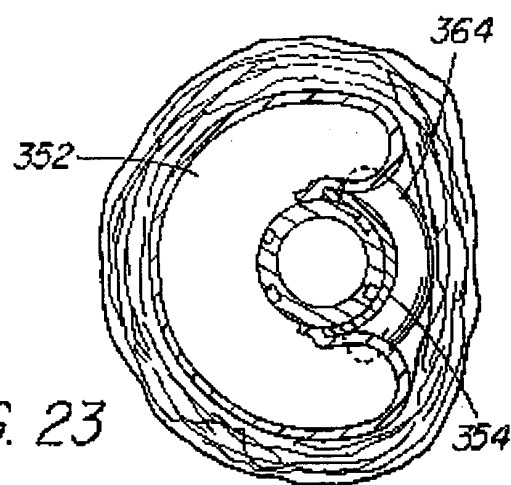
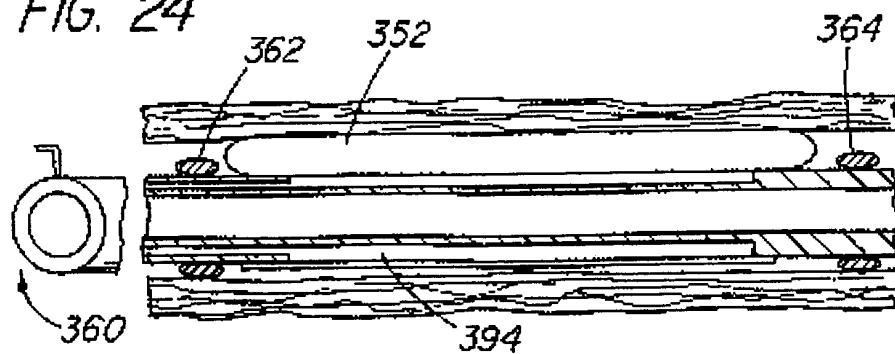
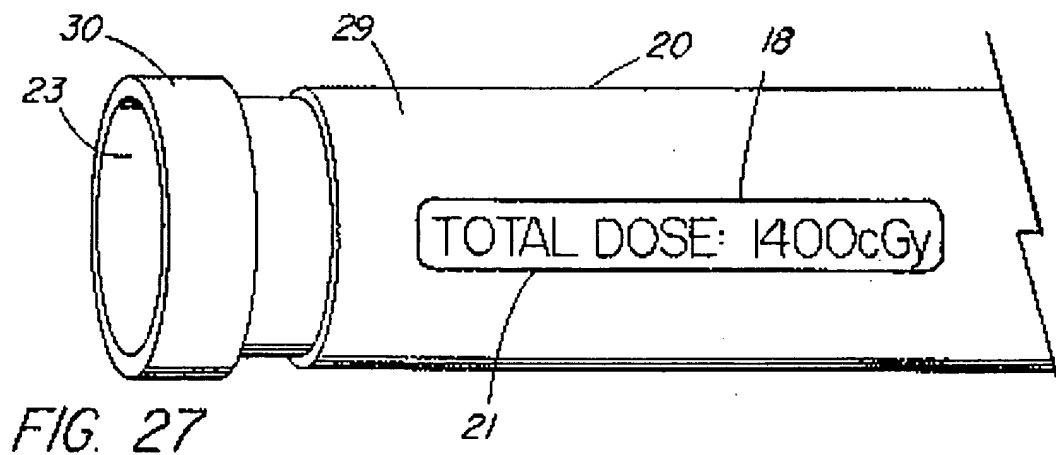
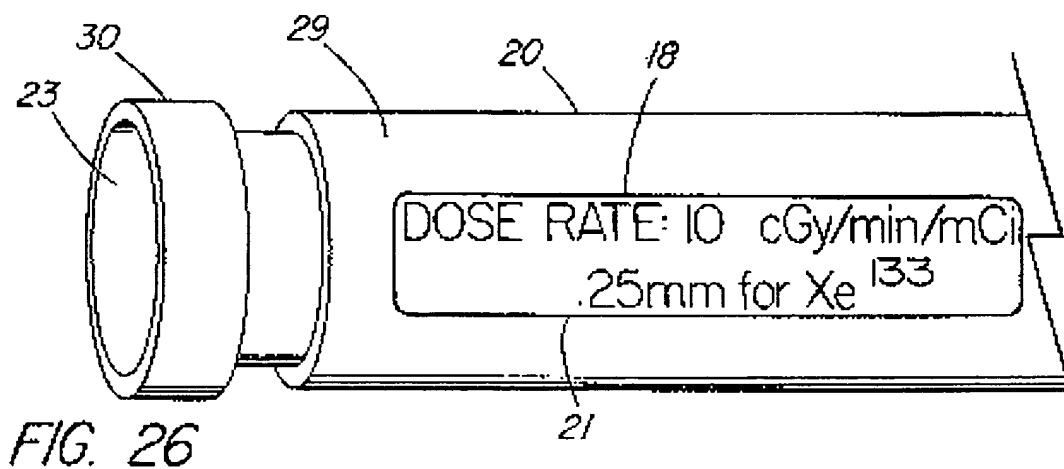
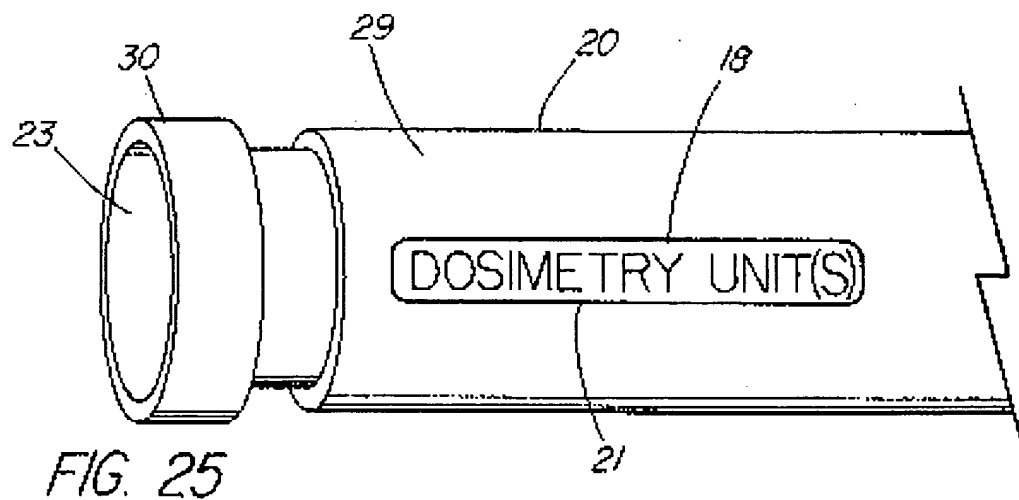


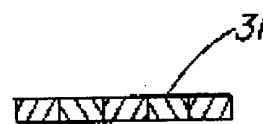
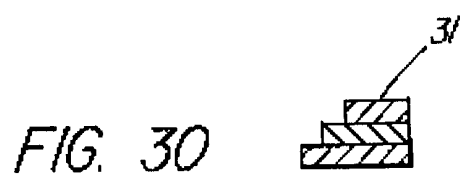
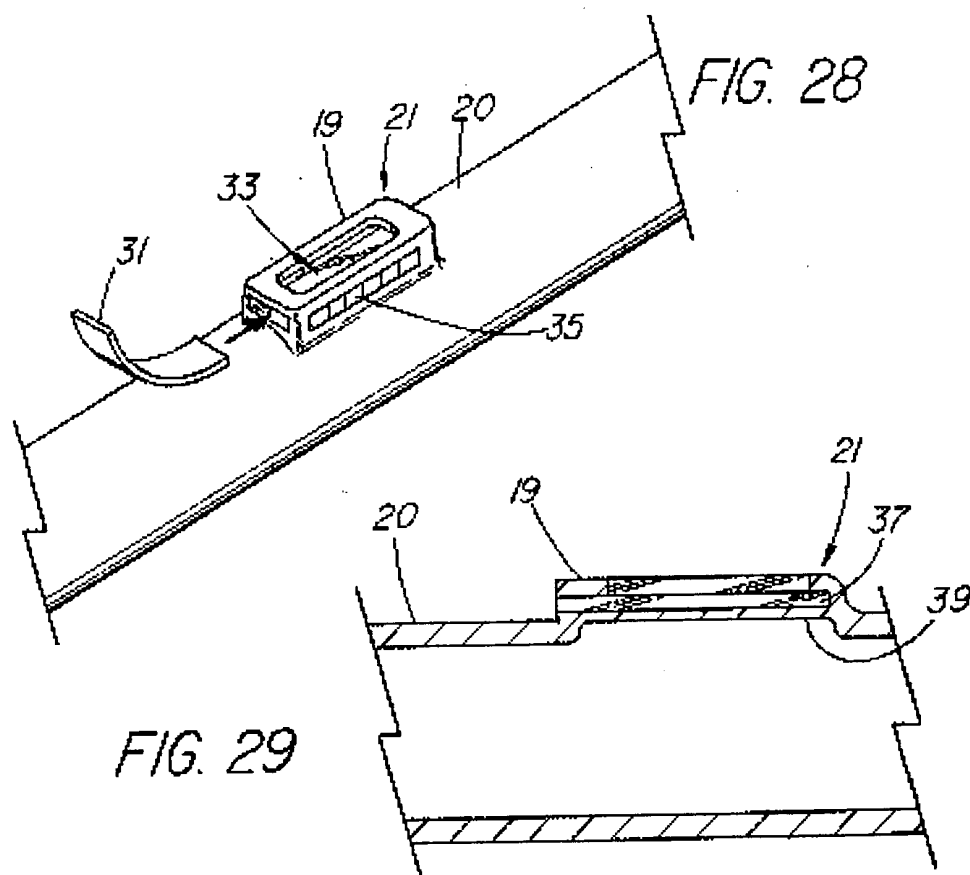
FIG. 24



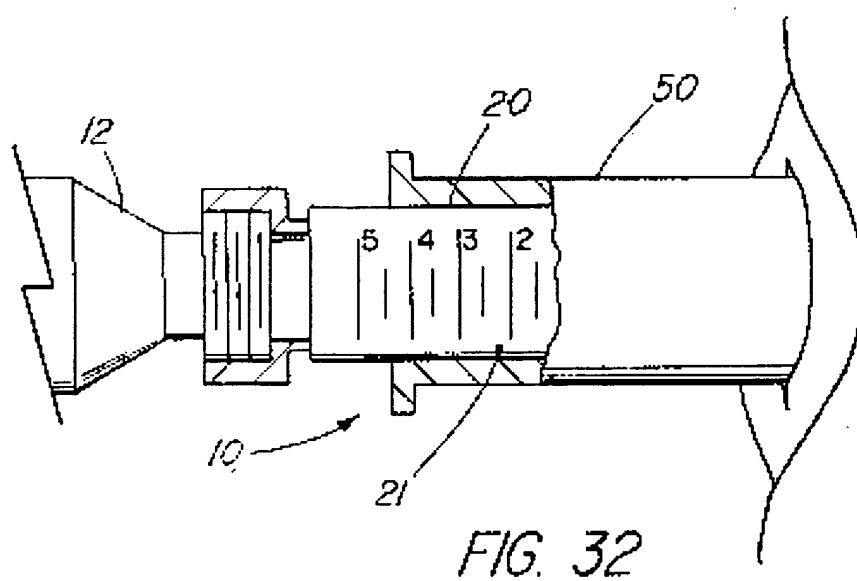
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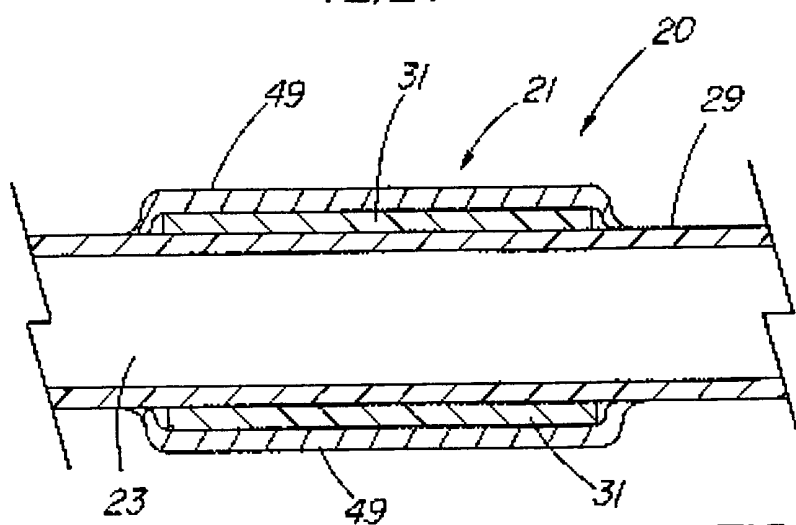


FIG. 33

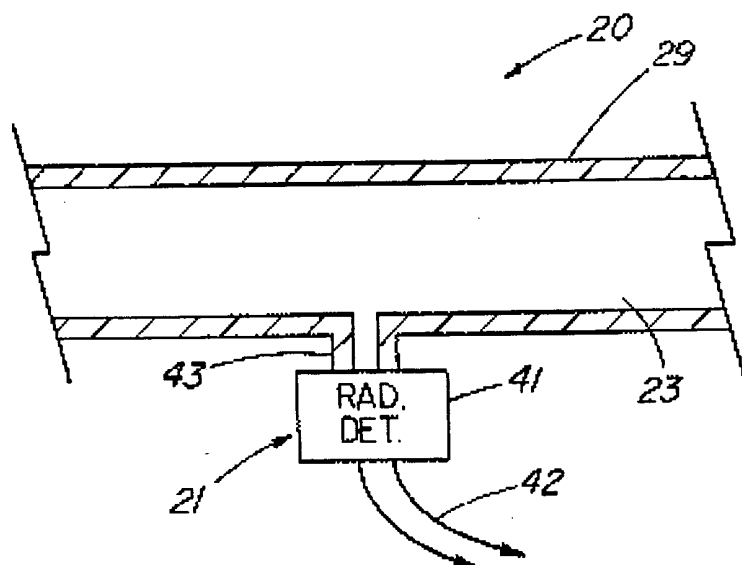
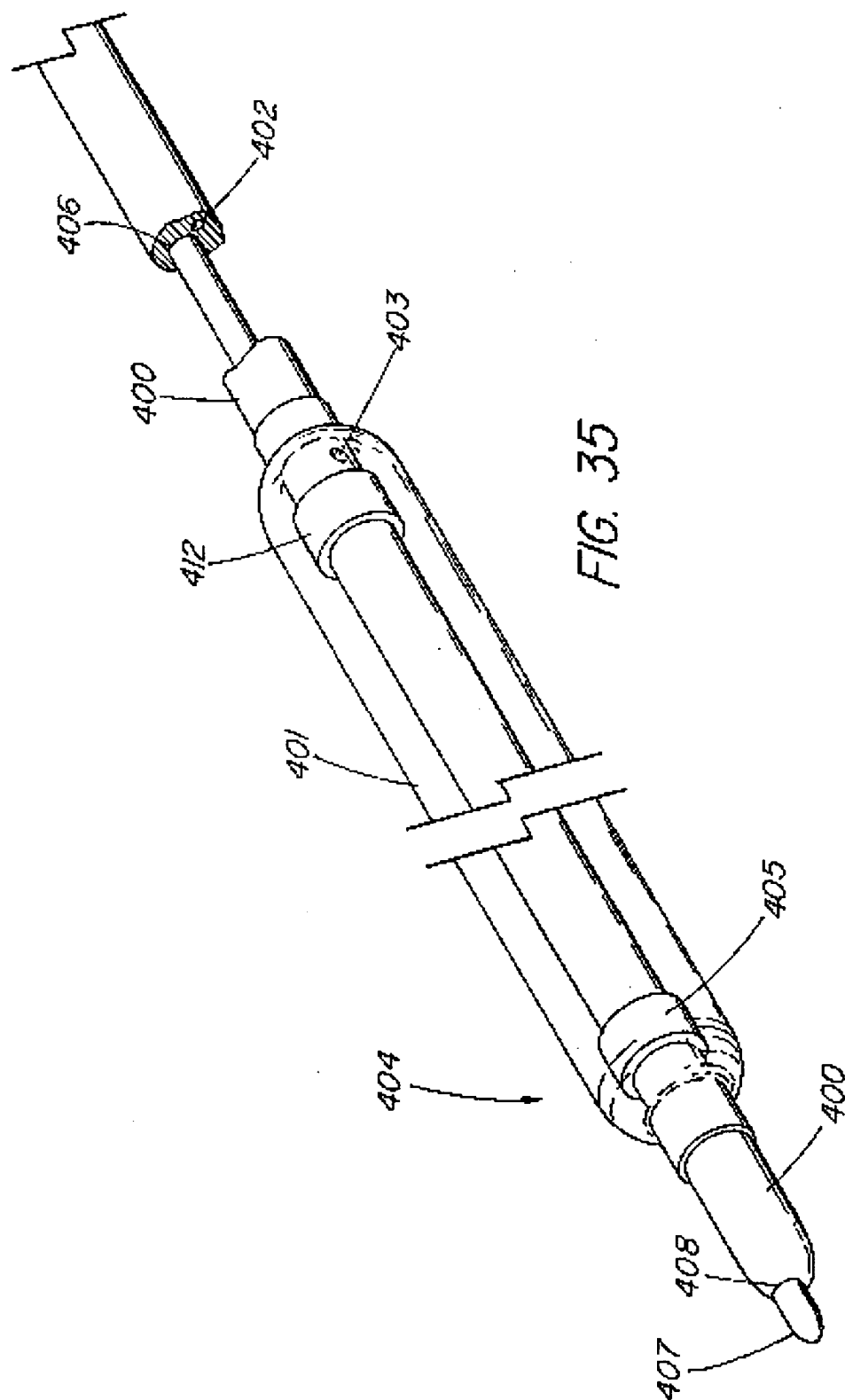
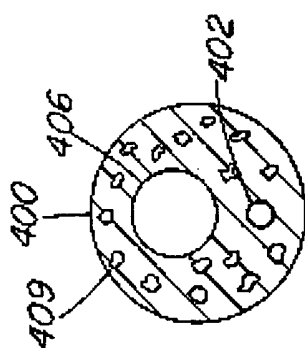
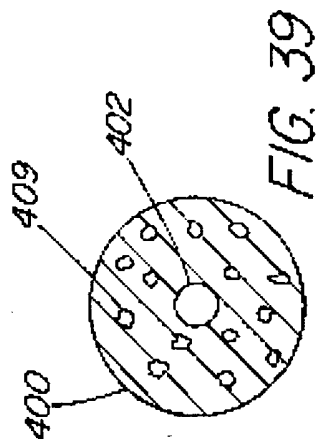
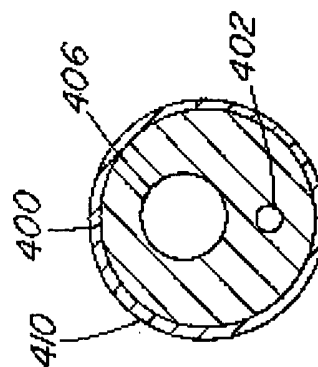
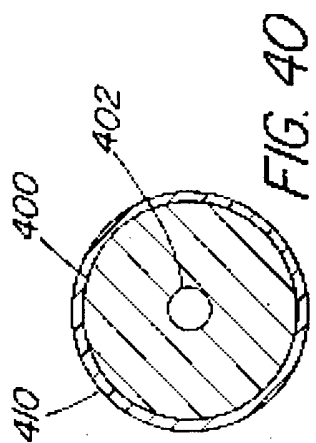
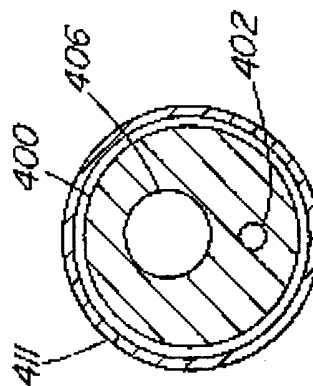
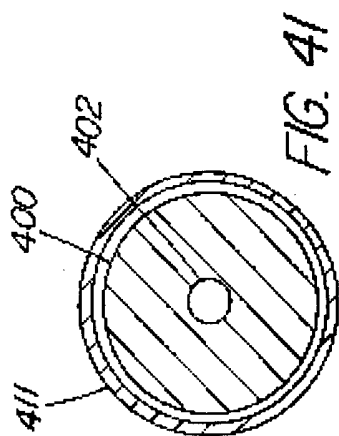


FIG. 34

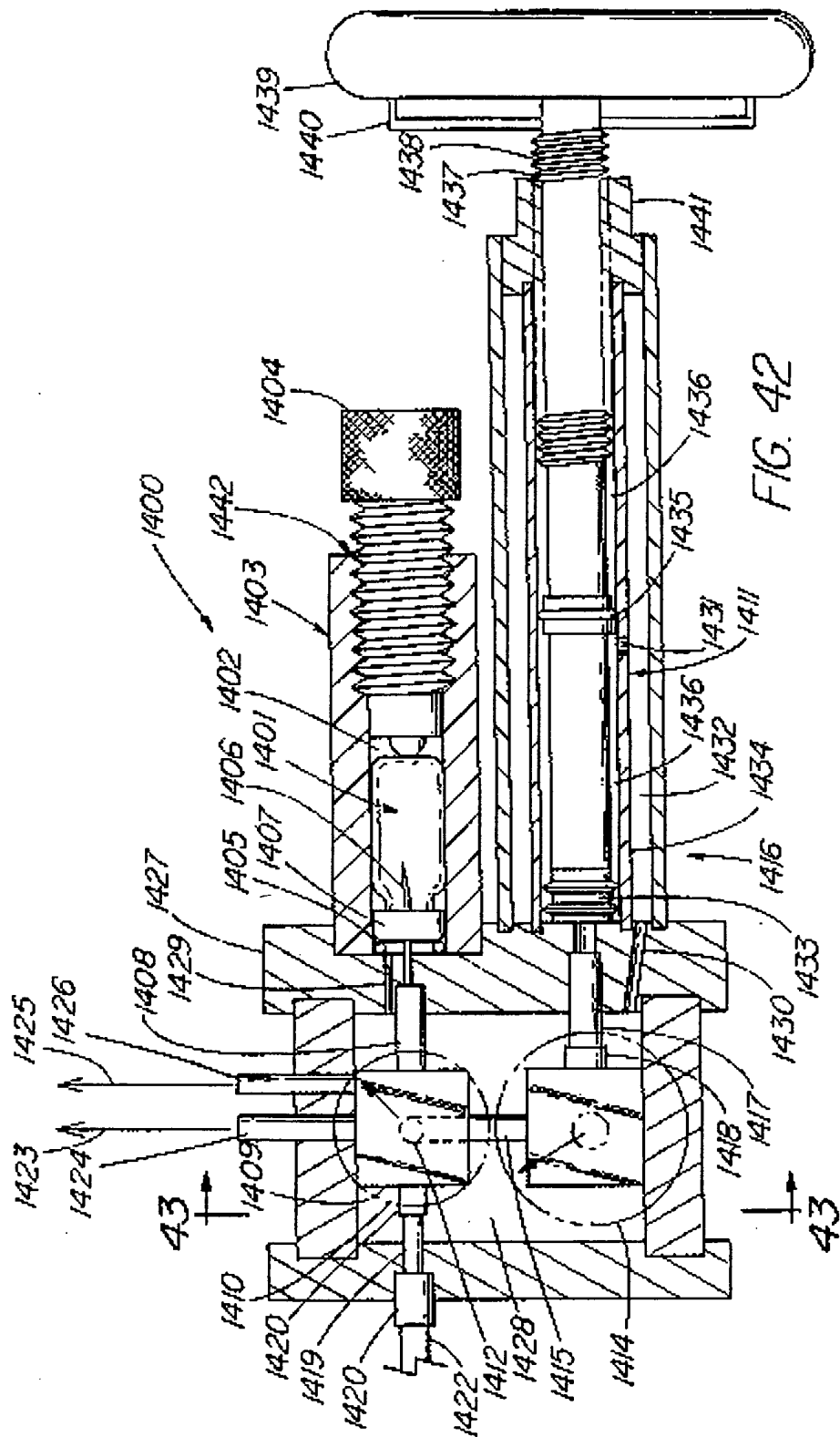
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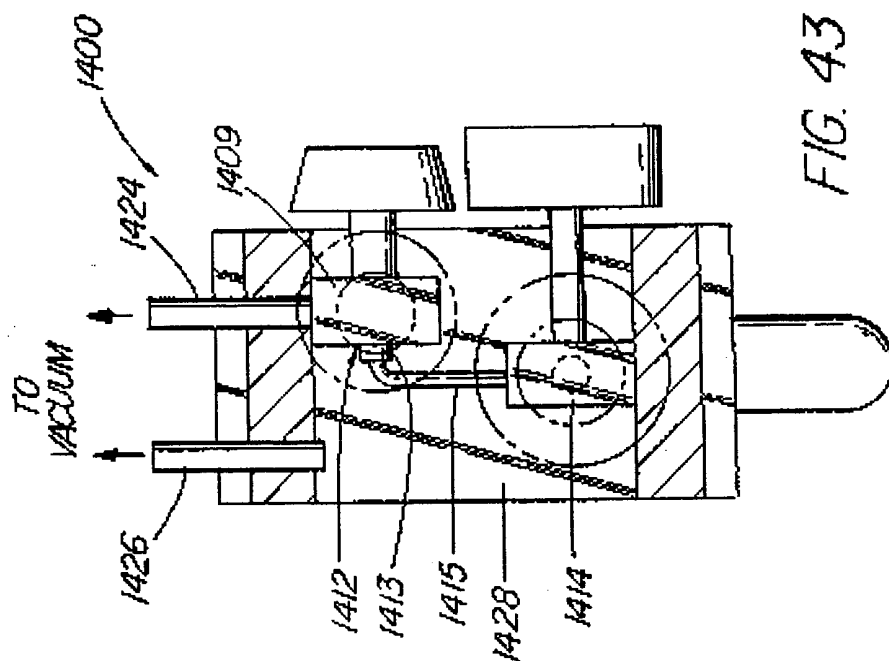
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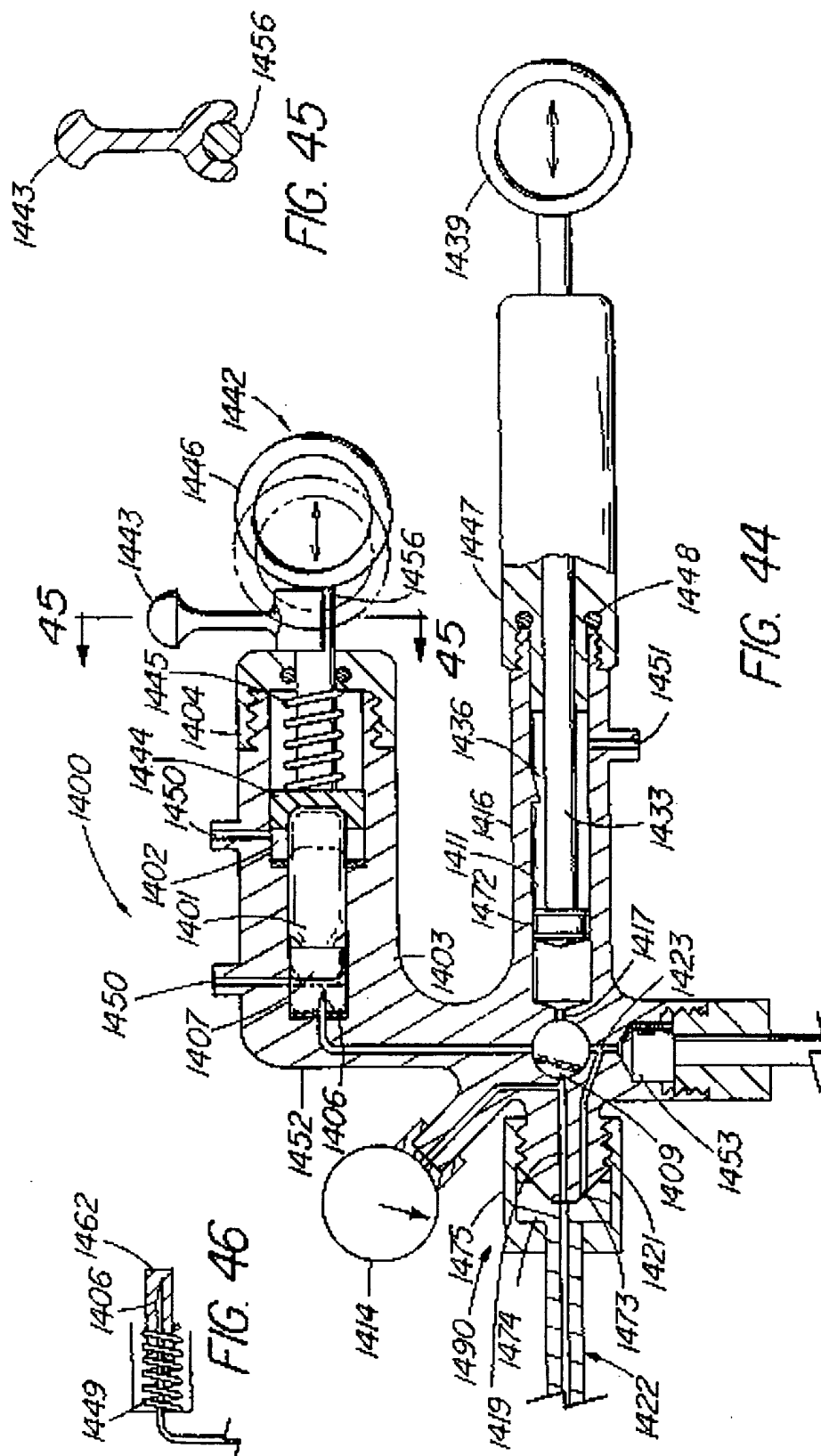


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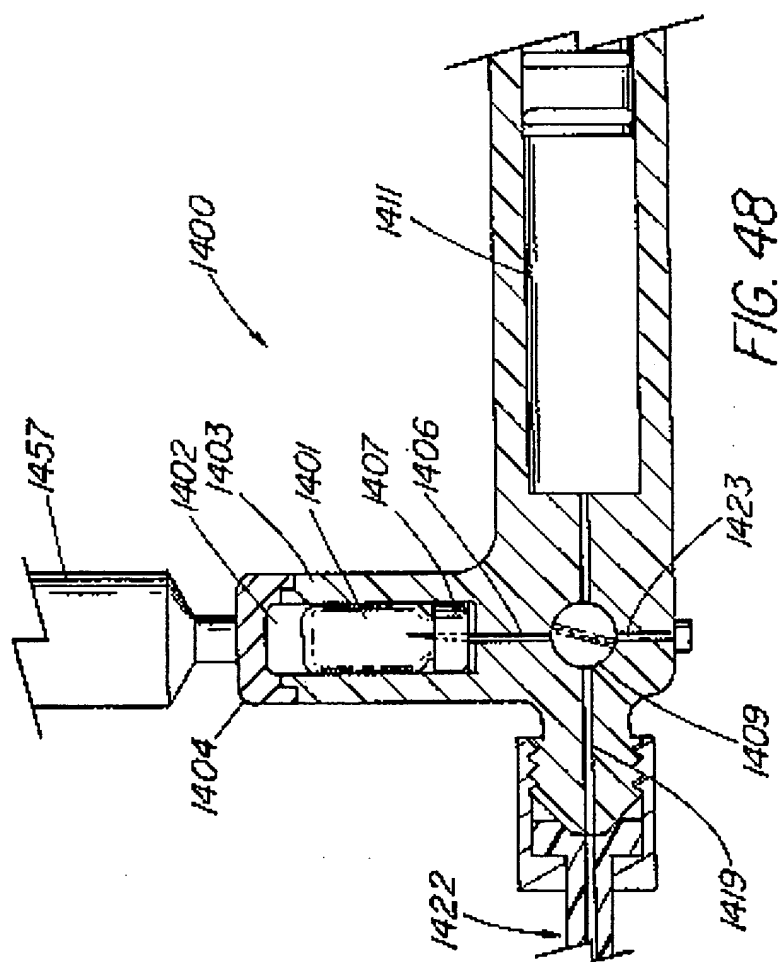


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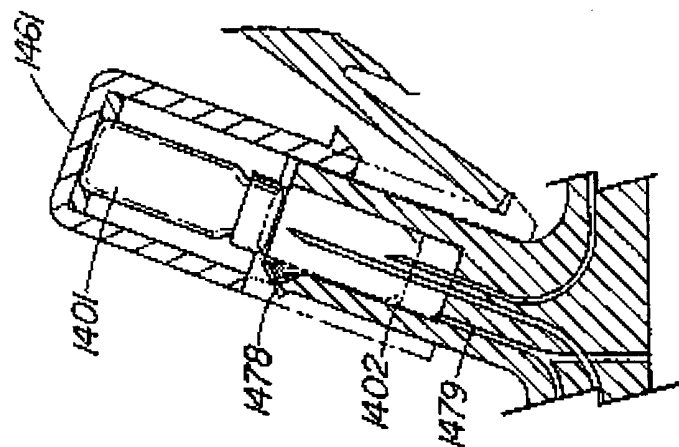


FIG. 50

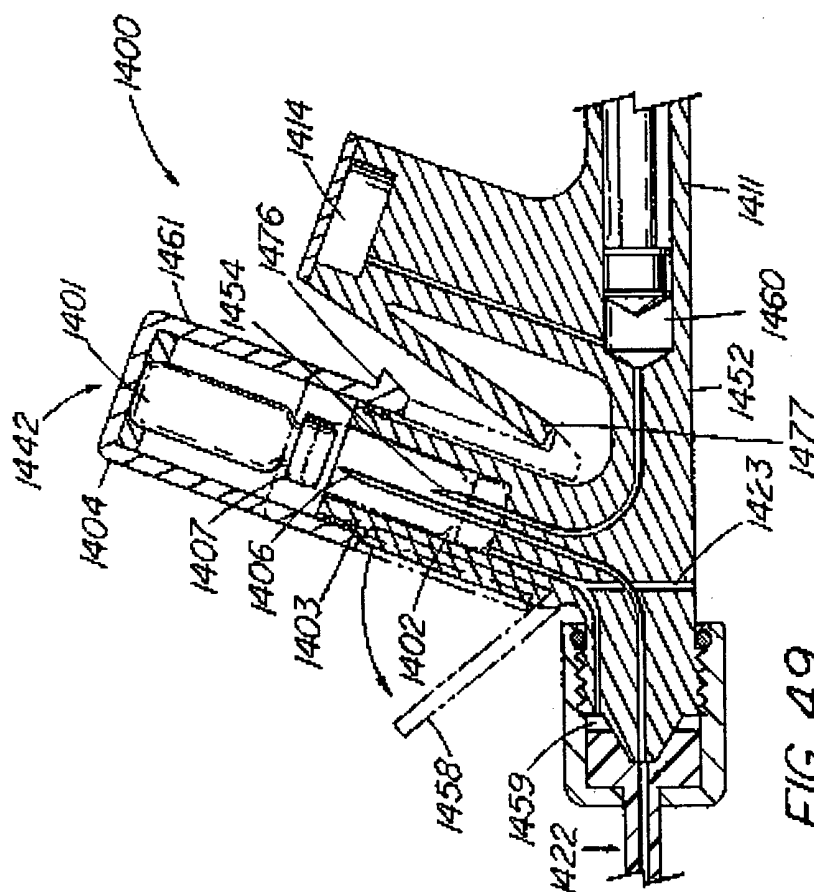
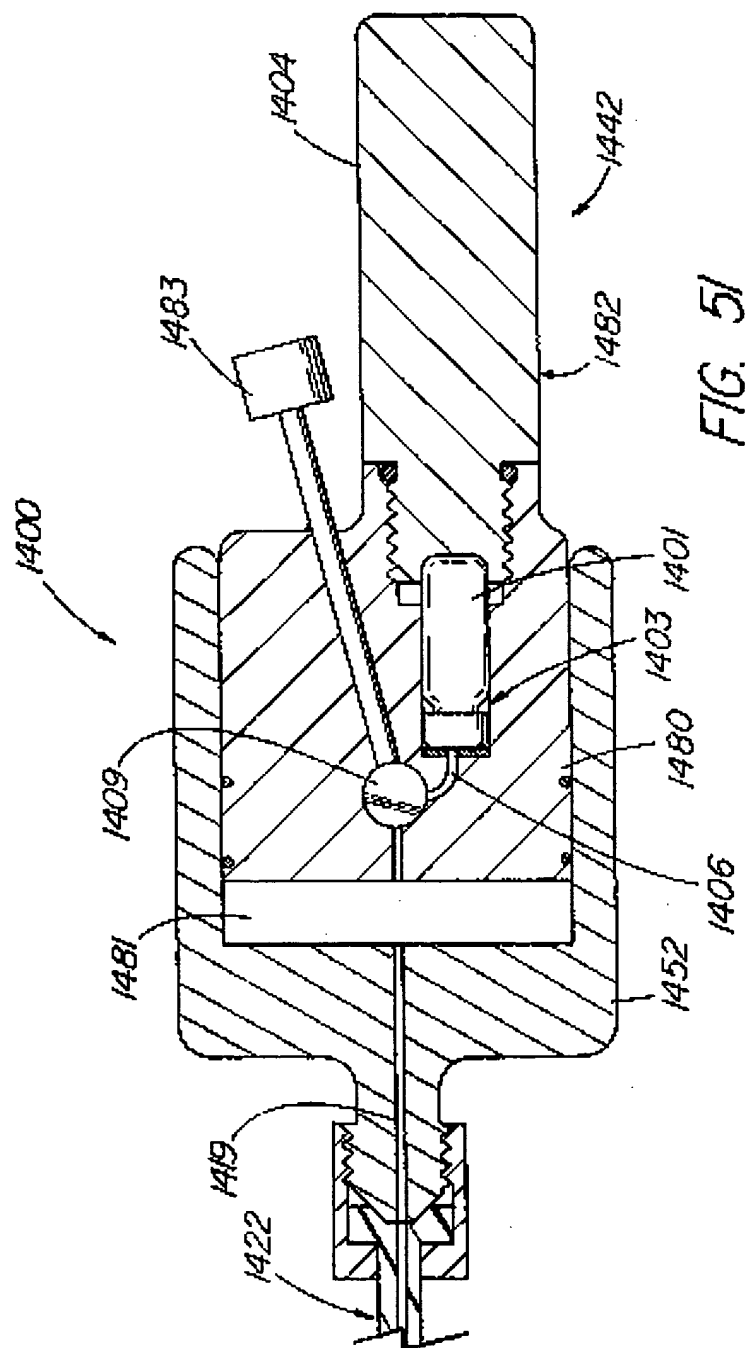


FIG. 49

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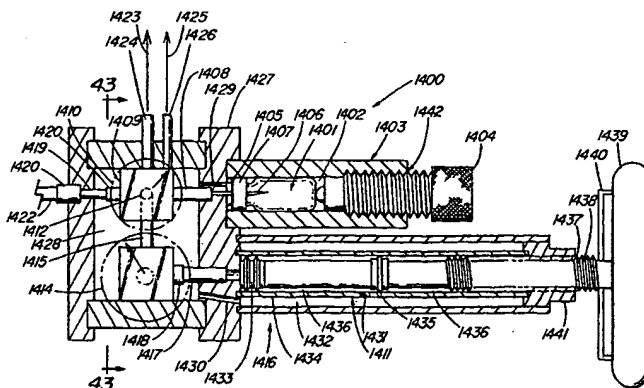




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: PCT/US98/25129 (22) International Filing Date: 1 December 1998 (01.12.98) (30) Priority Data: 60/070,262 31 December 1997 (31.12.97) US 60/075,284 20 February 1998 (20.02.98) US (71) Applicants (for all designated States except US): COOK INCORPORATED [US/US]; 925 South Curry Pike, P.O. Box 89, Bloomington, IN 47402-0489 (US). MED INSTITUTE INC. [US/US]; 1400 Cumberland Avenue, West Lafayette, IN 47906 (US). (72) Inventors; and (75) Inventors/Applicants (for US only): APPLE, Marc, G. [US/US]; 1606 Sycamore Hills Drive, Fort Wayne, IN 46804 (US). BATES, Brian, L. [US/US]; 3718 Exeter Lane, Bloomington, IN 47401 (US). DEFORD, John, A. [US/US]; 6051 Alik Mews, Bloomington, IN 47408 (US). FEARNOT, Neal, E. [US/US]; 3051 Hamilton Street, West Lafayette, IN 47906 (US). PURDY, James, D. [US/US]; 2008 Perrine Street, Lafayette, IN 47904 (US). (74) Agent: GODLEWSKI, Richard, J.; 1400 Cumberland Avenue, West Lafayette, IN 47906 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> (88) Date of publication of the international search report: 16 September 1999 (16.09.99)	

(54) Title: APPARATUS FOR SUPPLYING RADIOACTIVE GAS TO A DELIVERY DEVICE



(57) Abstract

Disclosed is a catheter apparatus filled with a radiation carrier material such as an inert radioactive gas for the treatment of restenosis after angioplasty, and malignancies. The inflated catheter includes a single unit or alternatively, a plurality of discrete chambers for transporting the radioactive carrier material and through which, blood may continue to flow during treatment with the prescribed radiation. When the radioactive carrier is a gas such as Xenon 133, an injection apparatus (1400) may be used that permits use of a standard radioactive gas source vial (1401) that may be loaded into the radioactive source vial enclosure or chamber (1403). The means for enclosing the vial (1404) may also serve as an urging mechanism (1442) to urge the source vial (1401) toward one or more piercing cannulae (1406, 1454) which permit delivery of the radioactive gas to the catheter. In one series of embodiments, the radioactive gas is withdrawn through a selector means (1409) such as a multiple position valve into a gas-tight variable volume chamber (1411) such as a syringe which then is deployed to deliver the gas into the catheter. Following treatment, the gas is withdrawn into the syringe and returned to the source vial (1401). In another series of embodiments a syringe filled with a liquid is used to displace the gas either directly into the delivery catheter (1422), or into a second syringe which injects the gas to the delivery catheter (1422).

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/25129

A. CLASSIFICATION OF SUBJECT MATTER		
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According to International Patent Classification (IPC) or to both national classification and IPC ⁶		
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A	US 4565301 A (HUBBARD, R. et al.) 21 January 1986, the whole document. -----	1-4, 6
<input type="checkbox"/> Further documents are listed in the continuation of box C. <input type="checkbox"/> Patent family members are listed in annex.		
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ANNEX

to the International Search
Report to the International Patent
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ANNEXE

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IS A 4192438	11-03-1980	keine - none - rien	
IS A 4565301	21-01-1986	JP A2 59005999	12-01-1984